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THE
DOCTRINE of ECLIPSES,

BOTH
SOLAR and LUNAR;
CONTAINING
SHORT AND EASY PRECEPTS FOR COMPUTING
SOLAR and LUNAR ECLIPSES.

THE
GENERAL and GEOGRAPHICAL PHÆNOMENA
OF
SOLAR ECLIPSES.

THE
PHÆNOMENA of SOLAR ECLIPSES
FOR ANY PARTICULAR PLACE,
WITH OR WITHOUT PARALLAXES,
FULLY AND CLEARLY EXPLAINED, FROM THE LATEST DISCO-
-VERIES AND IMPROVEMENTS; WHEREBY ANY PERSON OF
A MODERATE CAPACITY MAY BE ABLE IN A SHORT
TIME TO SOLVE THOSE GRAND AND SUBLIME
ASTRONOMICAL PROBLEMS.

WITH
CORRECT ASTRONOMICAL TABLES
FROM A MANUSCRIPT COPY OF THE
TABULÆ DUNELMENSES,
FITTED TO THE
MERIDIAN OF GREENWICH.

*Ne Mira Temporis Inclinatio foret, ob Eclipsin Obscuratam, discer-
-ciati Regum Animi Quoniam; Gentes Dimidias Triste obumbrat
Crepusculum.*

By BLITH HANCOCK, K
TEACHER of the MATHEMATICS.

NORWICH:
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TO THE

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RECTOR OF ASTERBY, IN LINCOLNSHIRE,
AND MASTER OF THE FREE GRAMMAR
SCHOOL, NORWICH.

SIR,

*YOUR character as a scholar will
be a sufficient apology for my desiring the honor of
inscribing the following sheets to you, not doubting
but that your goodness will pardon the liberty I
take, as it will afford me an opportunity of testi-
fying the high respect and esteem with which
I am,*

Sir,

Your most devoted,

Most obedient, and

Most humble Servant,

BLITH HANCOCK.

[11]

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RECTOR OF ASTREY, IN LINCOLNSHIRE,
AND MASTER OF THE FREE GRAMMAR
SCHOOL, NORWICH.

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but that your goodness will pardon the liberty I
take, as it will afford me an opportunity of re-
ferring the high school from which which

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I am,

Yours most devoted,

Wm. Hancock,

My humble servant,

WILLIAM HANCOCK.

P R E F A C E.

STUDY in general is necessary to mankind, and essentially contributes to the happiness of those who have experienced that active curiosity which induceth them to penetrate the wonders of nature.

“ It is not sufficient,” “ says Seneca, to know
 “ what we owe to our country, to our family,
 “ to our friends, and to ourselves, if we have
 “ not strength of mind to perform those duties;
 “ it is not sufficient to establish precepts, we
 “ must remove impediments, *ut ad præcepta,*
 “ *qua damus possit animus ire, solvendus est.*”

(Epist. 95.) Nothing answers better this purpose than the application to the study of the system of the world; the wonders which are discovered captivate the mind, and occupy it in a noble manner; they elevate the imagination, improve the understanding, and satiate the heart.

The greatest philosophers of antiquity have been of this opinion: Pythagoras was accustomed to say, that men should have but two studies; that of nature, to enlighten their understandings; and of virtue, to regulate their hearts. In effect, to become virtuous, not thro' weakness, but by principle, we must be able to reflect and think closely; we must, by dint of study, be delivered from prejudices which make us err in our judgments, and which are so many impediments to the progress of our reason, and the improvement of our mind. Plato held the
 study

study of nature in the highest esteem; he even goes so far as to say, that eyes were given to man to contemplate the Heavens.

The knowledge of the system of the world has delivered us from the apprehensions which ignorance occasions; can we recal without compassion the stupidity of those people who believed, that by making a great noise when the Moon was eclipsed this Goddess received relief from her sufferances, or that eclipses were produced by enchantments.

The knowledge of the system of the world has dissipated the errors of Astrology, by whose foolish predictions mankind had been so long abused. Hence it was necessary that a spirit of Philosophy and research should spread itself among mankind, open their understandings, unveil the limits of nature, and accustom them not to be terrified without examination, and without proof.

To the knowledge of the system of the world are owing the improvements in Cosmography, Geography, and Navigation; the observation of the height of the Pole taught men that the earth was round; the eclipses of the Moon taught how to determine the longitude of the different countries of the world, or their mutual distances from East to West. The discoveries of the satellites of Jupiter have contributed more effectually to improve geographical or marine charts than a thousand years common practice in navigation; and when their theory will be better known, the method of longitudes will be still more exact and more easy; and nothing

thing seems to be wished for to render Navigation more perfect and secure, but a method for finding, with ease, the longitude at sea, which is now obtained by the appulses of the Moon to the Sun and fixed Stars; and if the navigators of this kingdom were initiated in Astronomy by able teachers, as is practised in other parts of Europe, their estimation would approach within twenty or thirty miles of the truth, whilst, in ordinary voyages, the uncertainty sometimes amounts to more than an hundred leagues, by which the lives and fortunes of thousands are endangered.

The utility, therefore, of the Marine to those kingdoms, where empire, power, commerce, even peace and war are decided at sea, proves that of the knowledge of the system of the world.

The actual state of the laws, and of the ecclesiastical administration, is essentially connected with the system of the world: St. Augustine recommended the study of it particularly for this reason; St. Hyppolite applied himself to it, as also many fathers of the church.

Agriculture borrowed formerly from the motions of the celestial bodies its rules and its indications; Job, Hesiod, Varro, Eudoxus, Aratus, Ovid, Pliny, Columella, and Menilius, furnish a great number of proofs of it. The Pleyades, Arc-turus, Orijon, Syrius, gave to Greece and Egypt the signal of the different works; the rising of Syrius announced to the Greeks the harvest, to the Egyptians the overflowing of the Nile.

Ancient chronology deduces from the knowledge and calculation of eclipses the most fixed
points

points which can be found, and in remote times we find but obscurity. The Chinese chronology is entirely founded upon eclipses, and we should have no uncertainty in the ancient history of nations, as to the dates, if there were always Philosophers. It is from the system of the world we borrow the division of time, and the art of regulating clocks and watches; and it may be said, that the order and multitude of our affairs, our duties, our amusements, our taste for exactness and precision, our habitudes, have rendered this measure of time almost indispensable, and have placed it in the number of the necessities of life.

Thus the manifold advantages which result from the knowledge of the system of the world, has caused it to be cultivated, and held in singular esteem by all the civilized people of the earth. The ancient Kings of Persia, and the Priests of Egypt, were always chosen amongst the most expert in this science. The Kings of Lacedemon had always Philosophers in their council. It is well known how much Ptolomeus, the second, King of Egypt, encouraged this science; for in his time flourished Hyparchus, Calimachus, Apallonius, Aratus, Bion, Theocritus, Conan, &c. But to conclude, the establishments of different philosophical societies in England, Scotland, France, Italy, Germany, Poland, Sweden, Russia, &c. have given the Monarchs, Nobility, and Gentry of those countries a taste for the more refined pleasures attending the study of the sciences, and particularly of the system of the world; and may this emulation continue till time itself shall be no more.

SECTION

An Explanation of the Terms of Art used in this Treatise.

Altitude, is the height of the Sun, Moon, or Stars, above the horizon, in an azimuth circle, counted in degrees, minutes, and seconds.

Azimuths, or Verticle Circles, are great circles intersecting one another in the Zenith and Nadir.

Amplitude, is an arch of the horizon contained between the rising and setting of the Sun, Moon, or any Star, and the East and West points of the horizon, and is numbered in degrees, minutes, &c. and is always of the same name with the declination of the Sun, Moon, or Star, either North or South.

Analogy is the same with proportion, and is frequently used for that word.

Angle, is made by the meeting of two lines in a point, and may be of any quantity less than 180° .

Angle of Incidence, in a solar eclipse, is made by a line drawn from the centre of the penumbra, at the beginning of an eclipse, to the centre of the earth's disk; this is called the first angle of incidence. The second is made by a line drawn from the centre of the penumbra to the centre of the disk, at the beginning of the central eclipse, viz. when the centre of the penumbra first touches the disk of the earth. And the third angle of incidence, is when all the penumbra falls within the earth's disk, and is formed by a line drawn from the centre of the earth's disk to the periphery thereof, in that point where the periphery of the penumbra last touches it in its total obscurity within the disk. This third angle of incidence can only happen when the Moon's true latitude is less than the difference of the semi-diameters of the penumbra and the earth's disk at the true time of the conjunction of the Sun and Moon.

Angle of Incidence, in a lunar eclipse, is made by a line drawn from the centre of the Moon, touching the axis of the Moon's orb in the centre of the earth's shadow at the times of the beginning or ending of the eclipse.

Angle, Parallaxic, is made by the intersection of a vertical circle with the ecliptic through the body of the Sun, Moon, or Star.

Angle of the Ecliptic and Horizon, is the same with the altitude of the nonagesima degree.

Angle of Direction, is made by the meeting of the axis of the Moon's orb with the axis of the globe in a point, and that point is always in the centre of the earth's disk.

Anomaly of the Sun or Moon, is their distance in signs, degrees, minutes, &c. from their aphelion.

Antecedentia, in Astronomy, is the same as retrogradation, or going back of the planets, viz. from Cancer to Gemini, &c. in their annual motions.

Aphelion, is that point in the solar system in which a planet is at its greatest distance from the Sun, and consequently its motion then the slowest.

Apogee, is when the Moon, or other planet, is at its greatest distance from the earth.

Apparent Conjunction of the Sun and Moon, is when a right line drawn through the centre of the planet does not pass through the centre of the earth by reason of the parallax.

Argument of Latitude, is the Moon's distance from her North node in degrees, minutes, and seconds.

Ascensional Difference, is the difference between the right and oblique ascension, being the space of time the Sun riseth, or set- teth, before or after six o'clock.

Ascendent, is the eastern part of the horizon, so that when the Sun, Moon, or Stars, are rising, they are said to be on the cusp of the ascendent.

Astronomical Hours begin at the meridians, and are reckoned from noon to noon.

Atmosphere, is the lower part of the region of air encompassing the earth to the height of about 50 miles.

Axis of the World, an imaginary line conceived to pass through the earth's centre from pole to pole.

Centrifugal Force, is that by which a body moving round another body, does endeavour to fly off from the centre of motion in a tangent to the periphery of the curve they describe.

Centripetal Force, is that by which any body moving about another body is drawn down, or towards the centre of its orbit, and is nearly the same with gravity.

Complement of an Arch, is what the arch want of 90° .

Complement, Arithmetical, wrote co. ar. is what any logarithm wants of 10. Thus let the logarithm 9.768345 be given, its co. ar. is 0.231655.

Conjunction, True, is when the Sun and Moon are in the same sign, degree, minute, and second; thus, 6.

Construction,

Construction, is the drawing lines, and forming a figure for demonstration.

Consequentia, is when a planet moves forward in order of the signs, as from Cancer to Leo.

Declination of the Sun, Moon, or Star, is their distance from the equator.

Digit, in Eclipses, signifies a twelfth part of the Sun's diameter in solar eclipses; but in lunar eclipses the digits may sometimes be 23, when all above 12 shows how far the shadow of the earth is over the Moon on either side.

Disk of the Sun, or Moon, are their round phases, or faces.

Disk of the Earth, is the difference between the Sun's horizontal parallax and that of the Moon, and is different at different times.

Diurnal, belonging to the day.

Ecliptic, a great circle of the sphere in which the earth performs her annual period.

Epaq, is a number shewing the difference between the common solar, and mean lunar year.

Horizon, a great circle of the sphere dividing the Heavens into two equal parts, called the upper and lower hemispheres.

Inclination of the Earth's Axis, is the angle formed by the axis of the earth and the axis of the ecliptic.

Mean Motion of the Sun, Moon, or any of the other Planets, is the motions set down in tables by supposing them to move equally in perfect circles.

Medium Celi, is the degree of the ecliptic which is upon the meridian at any time of the day or night.

Meridian Angle, is the angle formed by the ecliptic and the meridian at any given time of the day or night.

Nodes, are the points or intersections of the orbits of the planets with the ecliptic; the Moon's nodes are marked thus, ♋, ♏.

Nonagesima Degree, is the 90th degree, or highest point of the ecliptic at any time of the day or night.

Occident, the western part of the horizon, or that point of the ecliptic that sets with the Sun, Moon, or Star.

Opposition of the Sun, Moon, or Star, is when they are just six signs, or 180 degrees distant, and is thus marked, ☊.

Orient, the eastern part of the horizon, or that point of the ecliptic that rises with the Sun, Moon, or Star.

Parallax, is an arch of a great circle passing through the Zenith and the true place of the Sun, Moon, or Star, and intercepted between the true and apparent place.

The Parallaxes are of five sorts, viz. in right ascension, declination, altitude, longitude, and latitude.

Path of the Vertex, is a circle described by any point of the earth's surface as it turns on its axis, and is always considered as vertical to the earth's centre, and in fact is the same as what we call the vertex, or Zenith, as being the point directly over our head; the semi-diameter of this path of the vertex is always equal to the complement of the latitude of the place that describes it.

Penumbra, is a faint shadow, or utmost edge of the perfect shadow which happens at the time of a lunar eclipse.

Perigeon, a point in the Heavens where a planet is at its nearest distance from the earth; so when the mean anomaly of the Moon is just six signs, she is then said to be in perigee, and this point is always diametrically opposite to the apogee, extended by the transverse-diameter of her elliptical orbit.

Perihelion, is a point in the Heavens where any of the primary planets, or comets, are nearest to the Sun, and their motions the swiftest.

Phases are the several appearances of an eclipse. *or of the Sun*

Phænomena, appearances in the Heavens.

Phænomenon, any single appearance.

Precession, or Recession, of the Equinoxes, is the going back of the equinoctial points 50 seconds yearly.

Right Ascension of the Sun, Moon, or Stars, is that degree of the equinoctial counted from the beginning, or Aries, which comes to the meridian with the Sun, Moon, or Star.

Time of Incidence, is the time from the beginning to the middle of an eclipse, and in a lunar eclipse is always equal to the time of half duration.

Time of Repletion, is the time from the middle of a solar eclipse to the end thereof.

Time

Time is a certain measure depending on the celestial motions, by which the distance and duration of things are measured.

Symbols are certain signs, or characters, made use of in the mathematical sciences, for the more clearly conveying of our ideas; those made use of in this treatise are the following, viz, S. signs, ° degrees, ' minutes, " seconds,

+, or the sign of addition, called plus, or more.

—, the sign of subtraction, called minus, or less.

×, multiplication. ÷, division. =, signifies equality.

√, signifies the square root of the number standing under it;

as $\sqrt{144}$ signifies the square root of 144. As ::, ::, : the sign of proportion; as 2 : 4 :: 3 : 6, and is thus read; as 2 to 4, so is 3 to 6.

♄, conjunction. ♅, opposition. ♆, node. ☾, Moon. ☼, Sun,

♈, Aries, the ram.

♉, Taurus, the bull.

♊, Gemini, the twins.

♋, Cancer, the crab.

♌, Leo, the Lion.

♍, Virgo, the virgin.

♎, Libra, the balance.

♏, Scorpio, the scorpion.

♐, Sagittarius, the archer.

♑, the goat. Capricorn.

♒, Equarius, the water-bearer.

♓, Pisces, the fishes.

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Fig. 5

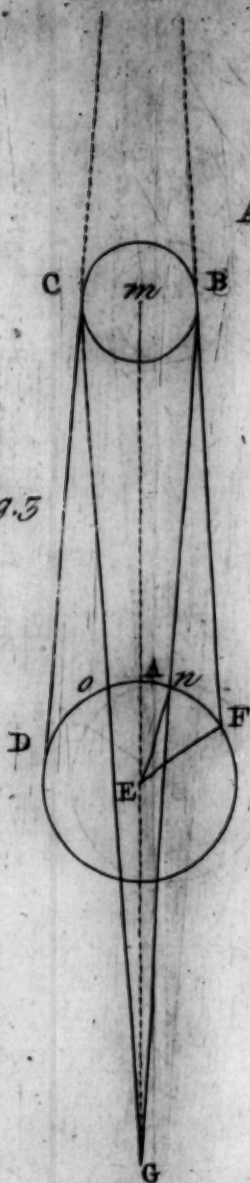


Fig. 2

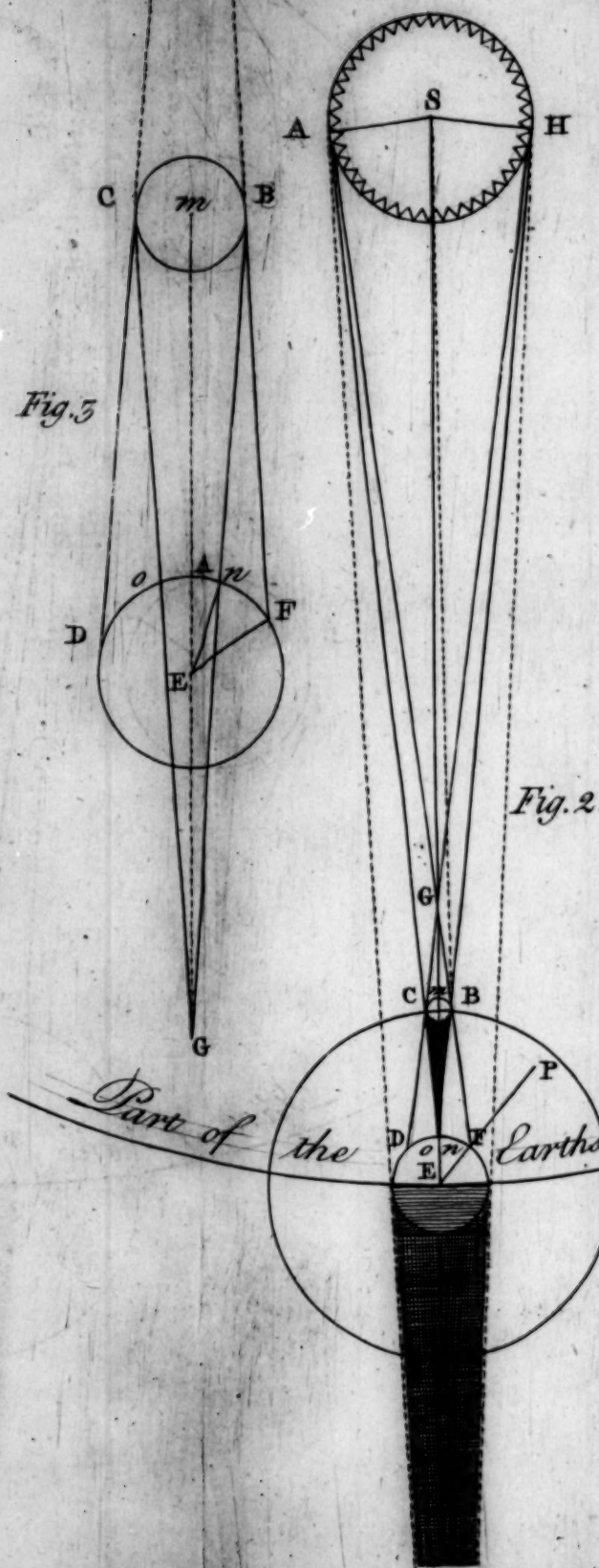


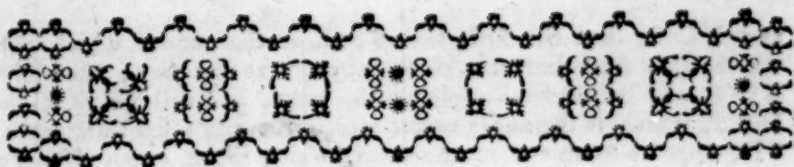


Fig. 1.



Fig. 2.

/P
Earth's Orbit



S E C T I O N I.

O F T H E

DOCTRINE of ECLIPSES.

THE design of this treatise is to explain the nature and cause of eclipses, and to render as clear as possible the method and mode of calculation, by plain and easy precepts, founded on the latest improvements, in order to enable the reader to compute for any time past, or to come, when these deficiencies of light did, or will happen, in either of the great luminaries of Heaven; also what the quantity thereof was, or will be, the precise time of their continuance when visible, or invisible, to us, or to any part of the globe: so that what the vulgar mind is unexpectedly surpris'd with, my readers will naturally look for, and know must happen, in consequence of those established laws of motion by which these bodies were regulated by the All-wise and Omnipotent Power that first created them.

Now, in order to explain this doctrine, we must first observe, that the Sun being a luminous body, one million times bigger than the earth, will enlighten considerably more than one half of it, and cause the earth to project a long conical shadow, as per Figure 1*, where S, is the Sun, E, the earth, and ABC, its shadow.

In order to determine the extent or magnitude of this shadow, we must note in the triangle SCD, that the outward angle, SBD, is equal to the sum of the two internal and opposite angles, BSC',

B

and

* Plate I.

and $BC'S$; but the first, viz. BSC , is that under which the the earth's semi-diameter, CB , appears at the Sun; therefore $BC'S$ will be the semi-angle of the cone, and will be equal to DBS , which is the angle under which the Sun's semi-diameter, SD , appears to an eye at the earth, which in its mean distance is $16': 5''$. This being premised, we may determine the cone's height; for in the right angled triangle, $CC'B$, are given $CB = 1$ semi-diameter of the earth, and the angle, $CC'B$, to find the side CC' in semi-diameters of the earth; for

As t. of $CC'B$. $16'. 5'$	—	—	—	7.670043
To radius	—	—	—	10.000000
So is 1 semi-diameter	—	—	—	0.000000
To CC' 213.8 semi-diameters of the earth				2.329957

Thus we find the height of the earth's shadow at a mean distance of the sun 213.8 semi-diameters; but when the Sun is at its greatest distance, his apparent semi-diameter, or angle, DBS , will then be $15': 49''$ only, whence proceeding as above we get CC' . 217.4 semi-diameters of the earth, which is the greatest height of the conical shadow of the earth, and is more than three times as great as the mean distance of the Moon, which is only 60.7 semi-diameters; but the height of the terrestrial shadow falls very far short of the distance of Mars, and therefore can involve no one of the heavenly bodies but the Moon only. In the same manner it may be shewn that the angle of the Moon's shadow (and indeed of all other spheres whose semi-diameters bear no sensible proportion to their distance from the Sun) is of the same dimensions with that of the earth, whence those cones are similar figures, and so have their heights proportional to the diameters of the bases. But the diameter of the earth is to the Moon's diameter nearly in the ratio of 100 to 28; therefore say, as the diameter of the earth 100 is to the diameter of the Moon 28, so is the altitude of the earth's shadow 213.8 to the altitude of the Moon's shadow 59.86 of the earth's semi-diameters. The shadow of the Moon, therefore, will not quite reach the earth in her mean distance, much less in her apogee; but in her perigee it will involve a small part of the earth's surface.

Besides the dark shadow of the Moon there is another, called the Penumbra, or partial shadow, as is represented in Figure 2nd*, where S is the Sun, E , the earth, and M , the Moon; and let ACO , and HBN , be two lines touching the opposite limbs of the Sun and Moon; then it is evident that $CONB$ will be the dark, or absolute shadow of the Moon, in which a person on the earth's surface, between O and N , is wholly deprived of the Sun's light. Moreover, let ABF , and HCD , be two other lines touching the

the sides of the Sun and Moon alternately, and intersecting each other in the point G above the Moon; then will DCBF be the penumbra above-mentioned, and is the frustum of the cone FGD; for 'tis evident that a part of the Sun will be seen, and part thereof hid to a spectator on the earth's surface, between O and D, and N and F; or, in other words, the Sun in those parts of the earth will appear only partially eclipsed. To calculate the angle of the cone, DGF, draw SB, then in the oblique angled triangle, BGS, the external angle, BGN, is equal to both the internal and opposite angles, GBS, and GSB; but GSB is that under which the semi-diameter of the Moon appears at the Sun, and is therefore insensibly small; whence the angle, BGM, equal GBS, or ABS equal the apparent semi-diameter of the Sun; therefore the part of the penumbral cone, CGB, is equal and similar to the dark shadow of the Moon.

Let us now see how much of the earth's surface can be at any time involved in the Moon's dark shadow, or the quantity of the arch no; in order to this, let us suppose the Sun to be in apogee, and the Moon in perigee, and in that case the height of the conical shadow will be about 61 semi-diameters, and the distance of the Moon about 56; that is (per Fig. 3d) $MG = 61$, $ME = 56$, and $EN = 1$. In this case also the semi-angle of the shadow $EGN = 15':50''$, as being least of all; therefore say,

As the side $EN = 1$	—	—	0.00000
To the side $EG = 5$	—	—	0.69897
So is S. semi-angle $EGN = 15':50''$	—	—	7.66324
To S. angle $ENG = 1^\circ:19':10''$	—	—	8.36221

Whence $ENG + EGN$ will be equal to $AEN = AN = 1^\circ:35'$ or the semi-angle of the cone; therefore ON will be $3^\circ:10'$ or the whole angle of the cone equal 190 geographic, or 220 statute miles, which is therefore the diameter of the dark shadow of the Moon on the earth's surface when greatest.

After a like manner you find the diameter of the penumbral shadow at the earth, as FNOD, when greatest of all; that is, when the earth is in perihelion, and the Moon in her apogee; for then will the Sun's apparent diameter be equal to $32':43''$; whence his semi-diameter $16':22''$ will be equal to the angle EGF, (see Fig. 2*) equal to the greatest semi-angle of the cone; from whence we find GM $58\frac{1}{2}$ semi-diameters of the earth. In this case also the distance of the Moon from the earth is $ME = 64$ semi-diameters; therefore,

B 2

As

(4)

As $EF \doteq 1$	—	—	—	0.000000
To $EG = MG + ME = 122\frac{1}{2}$	—	—	—	2.088136
So is S. angle $EGF, 16': 22''$	—	—	—	7.677498
To S. angle $GFP, = 35^\circ: 39': 31''$	—	—	—	9.765634

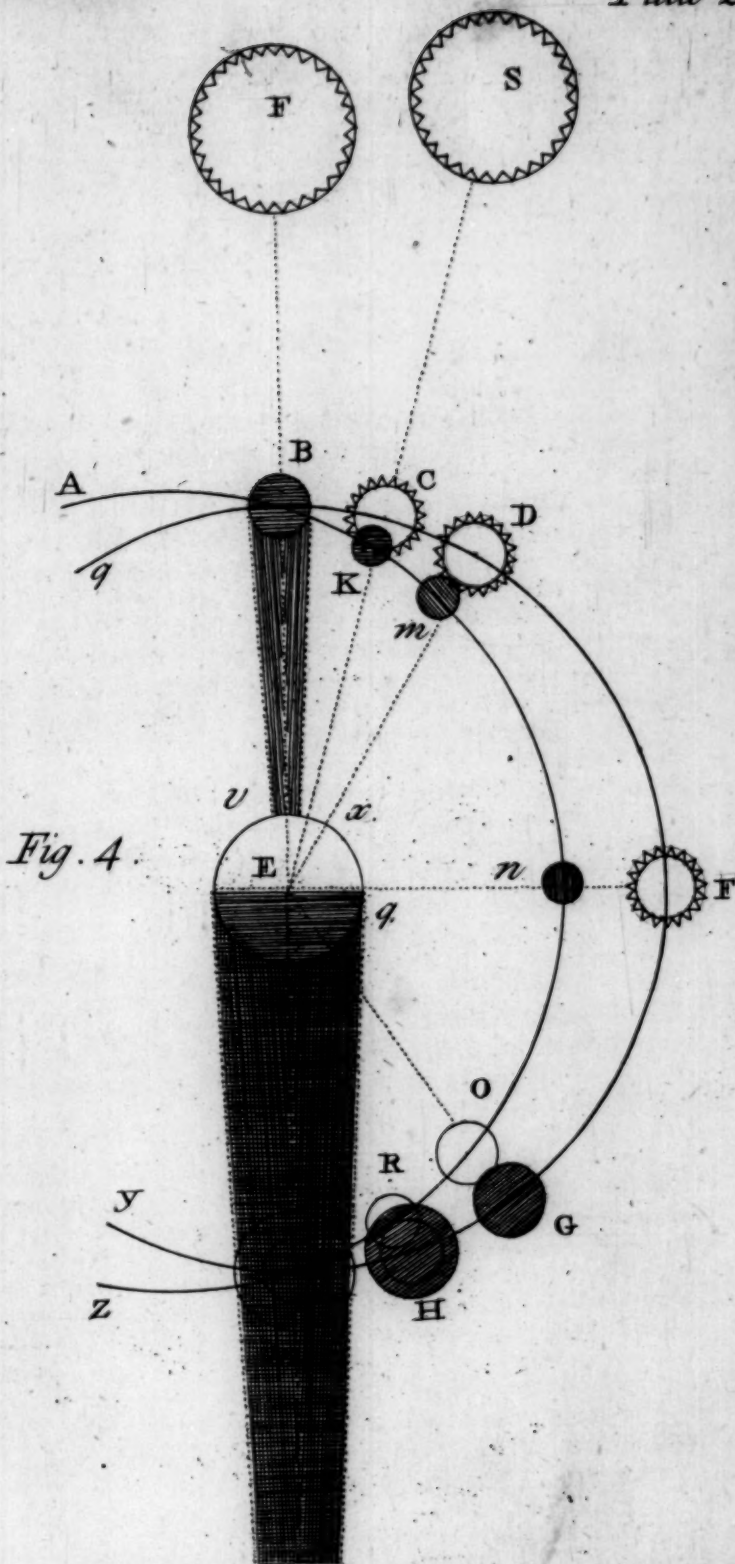
But $GFP = EGF + GEF$, and so $GEF = GFP - EGF = 35^\circ: 23': 9''$ whose double, viz. $.70^\circ: 46': 18''$ is equal $Fno D = 4246.3$ geographic miles, equal to 4919 miles British, or statute measure, nearly.

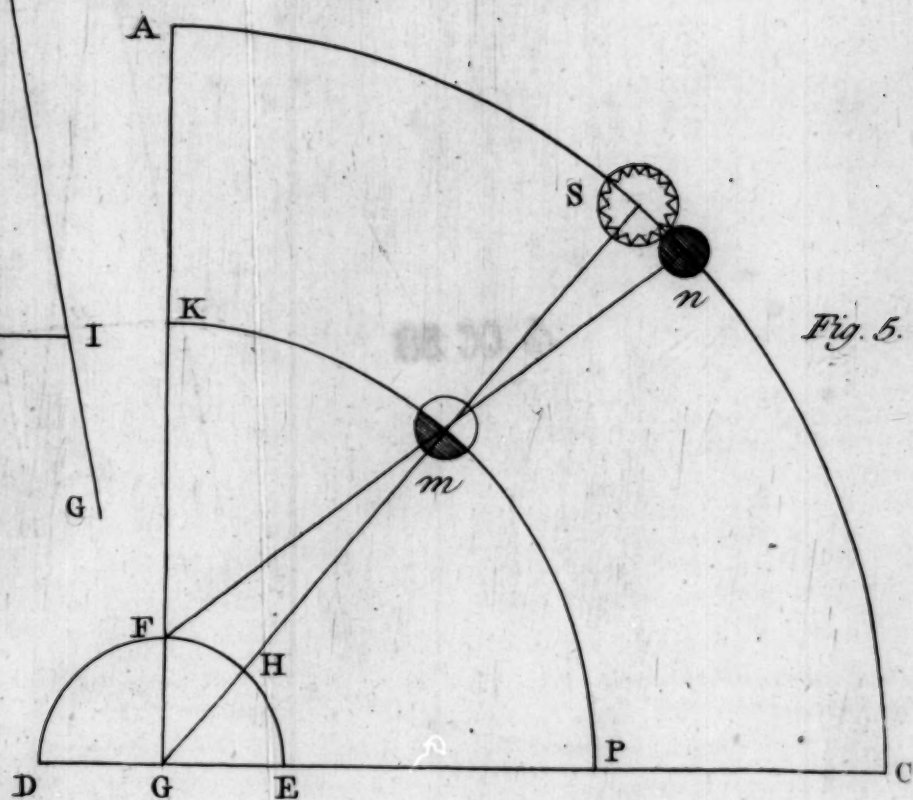
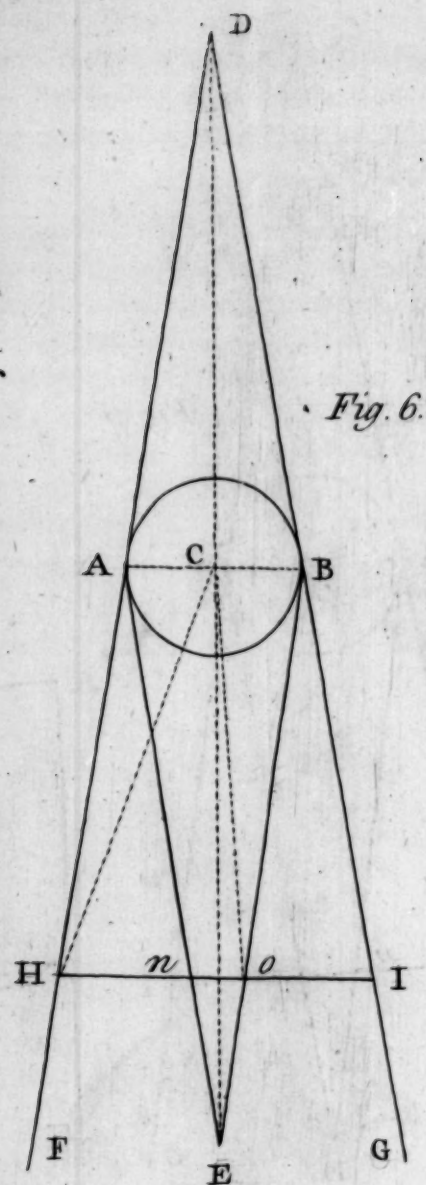
Since an eclipse of the Sun proceeds from an interposition of the Moon, 'tis evident, if the Sun and Moon were all ways in the same plane, there would necessarily be an eclipse of the Sun every time the Moon came between the Sun and earth; that is, at every new Moon: for (see Fig. 4) let F be the Sun, E, the earth, and $ABNZ$ the Moon's orbit in the plane of the ecliptic; then when the Moon comes to be at B, in the right line EF, which joins the centres of the Sun and earth, it will be exactly interposed between the Sun and a spectator on the earth at v; and since the apparent magnitude or disk of the Sun is the same nearly with that of the Moon, it must necessarily be hid behind the Sun's disk at that time, and so eclipsed from the sight of the spectator; and this must be the case whenever the Moon comes into the said line, or point, B; that is, at every new Moon. But if (as the case really is) the orbit of the Moon be not in the plane of the ecliptic, but inclined thereto under a certain angle, there may be a new Moon, and yet no eclipse of the Sun, at the same time.

Now, in order to illustrate this, let $qBCDFGY$ be a circle in the plane of the ecliptic described at the distance of the Moon's orbit, $AKNRZ$, and intersecting the same in the points B and M, making an angle therewith, as qBA , whose measure is the arch NF, as being 90° distant from the angular points, or nodes of the lunar orbit, B and M.

Now, 'tis evident, if the arch, NF, be somewhat greater than the sum of the apparent semi-diameters of the Sun and Moon, then at N, and some distance from N, towards B, there may be a new Moon, and yet no eclipse of the Sun, because in this case the disk of the Moon, N, is too much elevated, or depressed, above or below the apparent disk or face of the Sun, F, to touch it, much less to hide or eclipse any part thereof, as is evident from a slight inspection of Figure 4*.

But at a certain point, M, in the Moon's orbit, the Moon will have a latitude equal to the sum of the semi-diameters of the Sun





Sun and Moon, and therefore when the Moon is new at that point, she will appear to a spectator in the point x to touch the Sun only; from whence this point is called the ecliptic limit, in as much as it is impossible there should happen a new Moon in any part between this and the node, B , (on each side) without eclipsing the Sun less or more, as you may plainly see that the partial eclipse will happen at K , and the total eclipse in the very node itself, at B .

What I have hitherto been explaining has been with regard to the phenomena of an eclipse of the Sun, as they appear to a spectator on the earth's surface, in whose zenith the Moon then is, and where there is no refraction to alter the true latitude of the Moon; but where the Moon has any latitude, there the process of calculating the appearances of a solar eclipse will be somewhat more complex, on account of the variation of the Moon's latitude and longitude for every different altitude, and consequently every moment of the eclipse.

Now, in order to give a clear idea of this affair of refraction, let $A S N C$ (see Fig. 5*) be a quadrant of the Heavens, $D F E$, the surface of the earth, M , the Moon, and S , the Sun, seen from the centre of the earth; G , in the same point of the Heavens with the Moon, and consequently centrally eclipsed to a spectator at H , in whose zenith the Moon then is; but to a spectator any where else situated, the same phenomenon will not happen in the same circumstances, if at all.

For a spectator at F will view the Moon in the direction of the right line, $F M N$, and so her apparent place in the Heavens will be at N , where it is evident her upper limb will but just touch the lower limb of the Sun, and so will not eclipse it at all; but to a spectator any where between F and H , the Sun will appear to be partially eclipsed, less, or more, as the spectator is supposed to go from F towards H .

Now this arch, $S N$, in the Heavens, is what we call the parallax, as being the difference between the true and apparent place of the Moon at m , and is equal to the angle, $S M N$, or $F M G$; but this angle, or parallax, is constantly diminishing as the phenomenon at M approaches towards the zenith at K , where it entirely vanishes, but increases as it approaches the horizon at P , where it is greatest of all, and is there called the horizontal parallax, which in the Moon amounts sometimes to more than a whole degree.

It must be here observed, that the parallax always depresses the object, and therefore when the Moon has north latitude it is diminished, but the south latitude is increased with respect to us, and

and so the ecliptic limits are variable in every particular latitude; but a solar eclipse may in an absolute manner be best represented by a projection of the earth's disk, and of the section of the dark and penumbral shadow of the Moon, as they appear (or would appear) to a spectator, at the distance of the Moon in a right line joining the centres of the Sun and earth.

In order to this we are to find the dimensions of the apparent semi-diameters of the earth, dark shadow, and penumbra, at the distance of the moon. As to the earth's semi-diameter it is equal to the Moon's parallax, less the Sun's horizontal parallax, as will be shewn further on.

That of the dark shadow is thus estimated, Fig. 6*: Let C be the centre of the Moon, AB, its diameter, AEB, its dark shadow, and FDG, the penumbral cone; then let HI be the diameter of the penumbra at the earth, and *no* that of the dark shadow, draw Co and CH; then is the angle $\text{COB} = \text{BEC} + \text{ECO}$, and so $\text{OCE} = \text{BOC} - \text{BCE}$; that is, the apparent semi-diameter of the dark shadow is equal to the difference between the apparent semi-diameters of the Moon and Sun. In like manner the angle, $\text{HCE} = \text{AHC} + \text{ADC}$; that is, the apparent semi-diameter of the penumbra at the earth is equal to the sum of the apparent semi-diameters of the Moon and Sun. Now, the semi-diameters of the Sun and Moon, and also the Moon's horizontal parallax, are already calculated for the various distances of the Sun and Moon from the earth, and for the middle state of the lunar orbit, in the new and correct astronomical tables affixed to this work.

Let AB represent a small portion of the annual orbit, and CD the visible path of the centre of the lunar shadows, which will exactly correspond to the position of the Moon's orbit with respect to the ecliptic in the Heavens; and therefore the point of intersection Ω will be the node, and the angle, $\text{D}\Omega\text{B}$, the angle of inclination of the lunar orbit to the plane of the ecliptic, which is about five degrees. Hence, if EPQS represent the disk of the earth (according to the orthographic projection) in the several places ΩEFG , whose semi-diameter is made equal to the number of minutes in the Moon's horizontal parallax at the time of the eclipse; and if in the path of the shadows in the points ΩVWX , we describe a small circle, whose semi-diameter is equal to the difference between the semi-diameters of the Sun and Moon, that shall be the circular section of the Moon's dark shadow at the distance of the earth; and if on the same centre we describe a larger circle, whose semi-diameter is equal to the sum of the semi-diameters of the Sun and Moon, that shall represent the section of the penumbral shadow, as is here shewn by the fainter areas, $\Omega v, w, x$.

Here

Here then it is evident, if the Moon, when new, be at the distance, Ωx , from the node, the penumbral shadow will not fall near the earth's disk, and so there cannot possibly happen any eclipse. If the Moon's distance from the node be equal to Ωw , then the penumbral shadow will just touch the disk, and consequently ΩF will be the ecliptic limit, and may be found as follows: the line, WF , as being the nearest distance of the centres of the shadows and disk, is perpendicular to the path, CD , and is equal to $FO + OW = 61': 36'' + 16': 22'' + 16': 48''$, viz. the sum of the Moon's horizontal parallax, and of the semi-diameters of the Sun and Moon, all of them when greatest: also the angle triangle, $W \Omega F$, when least, is $5^\circ: 30'$; therefore in the right angled, $W \Omega F$, are given the angle, $W \Omega F$, $5^\circ: 30'$, and the side WF , $94': 46''$, to find the side, ΩF , which may be determined by the following analogy:

As S. $W \Omega F$, $5^\circ: 30'$	—	—	8.981573
To radius	—	—	10.000000
So is log. WF , $94'.76$	—	—	1.976655
To log. ΩF , $988'.7$	—	—	2.995052

The ecliptic limit, therefore, is $988'.7$, which is equal to $16^\circ: 28': 42''$, beyond which distance from the node Ω there can happen no eclipse; and within that distance, if the Moon be new, the shadow will fall on some part of the disk, as at E ; where all those places over which the shadows pass will see the Sun eclipsed in part only, by the faint penumbral shadow, but totally by the dark shadow; and the Sun will be centrally eclipsed to all those places over which the centre of the shadow passeth. If the Moon be new in the node itself, then will the centre of the shadows pass over the centre of the disk, as is represented at Ω . In this case, if the apparent diameter of the Moon be greater than that of the Sun, the face of the Sun will be wholly obscured to all parts over which the centre passes; but if not, the Sun will only be centrally eclipsed, and his circumference will appear a bright annulus, or luminous ring, whose width will be equal to the difference of the semi-diameters of the luminaries, whence this is called an annular eclipse.

As the disk of the earth is here projected it represents the case of an eclipse on an equinoctial day; so that Aq , is the ecliptic, $\mathcal{E}Q$, the equator, ZN , the axis of the ecliptic, PS , the axis of the equator, or of the earth, P and S the north and south poles, besides the tropics and polar circles here represented by right lines, as in the common analemma, or orthographic projection;

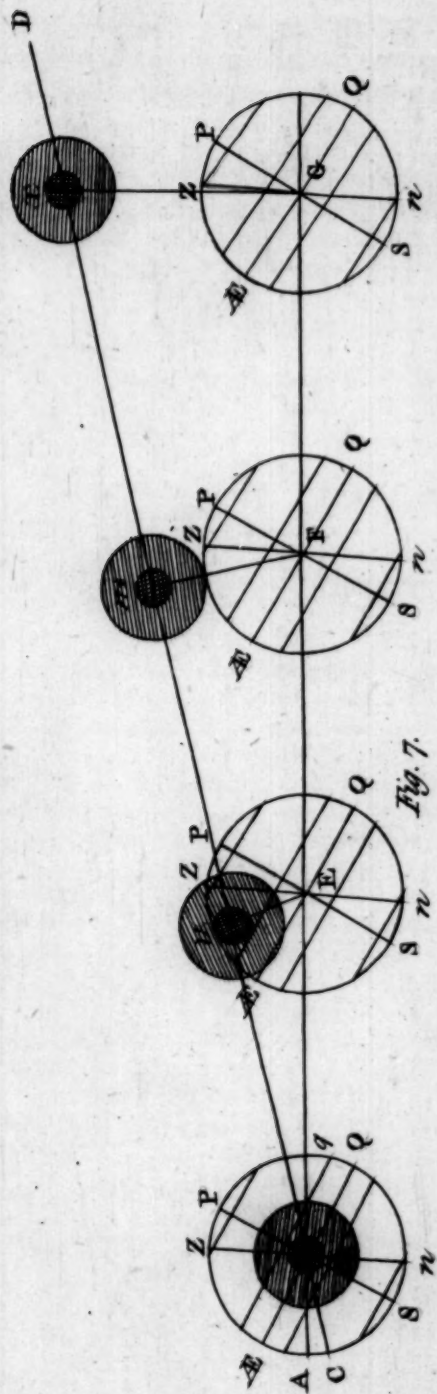
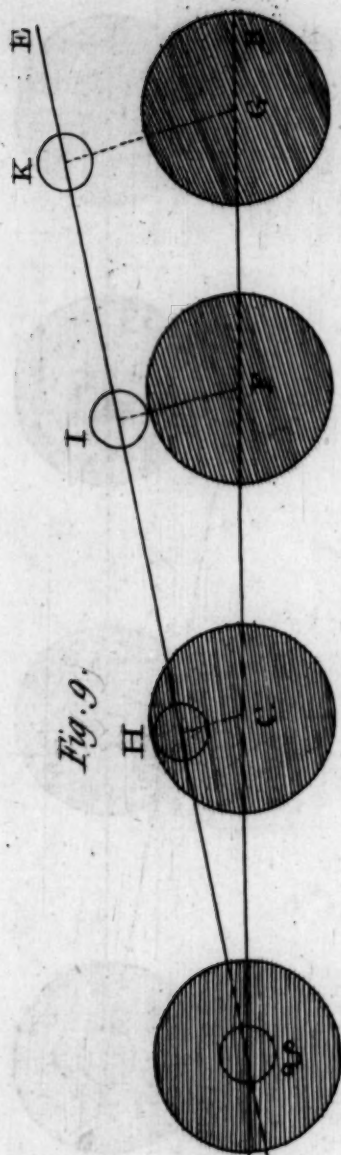
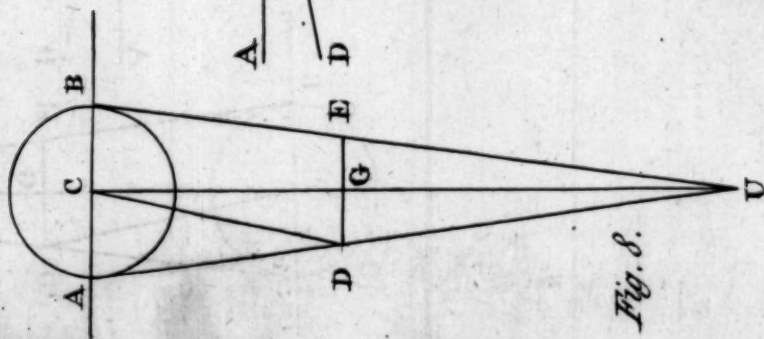
jection; and by those who understand this projection, the disk of the earth, and the passage of the shadows over it, may be exhibited for any place of the Sun, or declination of the Moon.

Lunar eclipses are not quite so complicated in theory, nor near so tedious and difficult in calculation, as solar ones. The latter are only apparent, the former really such; that is, the Moon is really deprived of its light, and therefore must appear obscured to all the inhabitants of the earth equally, by whom the can be seen; whereas the Sun, not being deficient in light, will ever appear resplendent to those who do not happen to live on that part of the earth where the lunar shadows pass. As a lunar eclipse is occasioned by the immersion of the Moon into the earth's shadow, we have only to calculate the apparent semi-diameter of the earth's shadow at the Moon, in order to delineate an eclipse of this sort: thus, let AB be the earth, C, its centre, AVB, its (see Fig. 8*) conical shadow, DE, the diameter of a section thereof at the Moon, and drawing CD, we have the external angle, ADC, equal to the sum of the two internal and opposite angles, DCV and DVC; therefore DCV will be equal to ADC; less DVC; that is, the angle, DCV, under which the semi-diameter of the earth's shadow at the distance of the Moon appears, is equal to the difference between the Moon's horizontal parallax, ADC, and the semi-diameter of the Sun, DVG. Let us, therefore, suppose AB to represent the path of the earth's shadow at the distance of the Moon near the ♄ node, and DE a part of the lunar orbit, and the section of the earth's shadow be delineated at ♄, C, F, G, and the full Moon at ♄, H, I, K; then it will appear evident, that where the least distance of the centres of the Moon and shadow exceeds the sum of their semi-diameters, there can be no eclipse of the Moon, as at G; but where that distance is less, the Moon must be partly or wholly (see fig. 9*) involved in the shadow, and so suffer an eclipse as at C, or ♄; in which latter case the Moon passes over the diameter of the shadow; but in a certain position of the shadow, as at F, the least distance of centres, IF, is equal to the sum of the semi-diameters; and therefore ♄F is the ecliptic limit for lunar eclipses; to find which we have IF equal to $63' : 1''$ when greatest, and the angle, I ♄ F 5° . Therefore say,

As S. I ♄ F, 5°	—	—	8.940296
To radius	—	—	10.000000
So is log. $63'.16 =$ Side IF	—	—	1.800442
To log. Side ♄ F, 724.7	—	—	2.860146

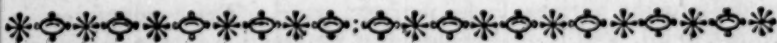
As

Plate 4.



Hence, if the Moon be at a less distance from the node, γ , than $724.7 = 12^{\circ} 4' 42''$, there will be an eclipse, otherwise none can happen.

If the earth had no atmosphere the shadow would be absolutely dark, and the Moon involved in it quite invisible; but by means of the atmosphere many of the solar rays are refracted into, and mixed with, the shadow by which the Moon is rendered visible in the midst of it, and appears of a dusky red colour.



S E C T I O N II.

Of the Equation of apparent Time.

HAVING endeavoured thus far to explain the nature and cause of eclipses, it remains that I should now shew how to reduce the same into practice in astronomical computation; but seeing all celestial motions are in astronomical tables adapted unto mean or equal time, and unless the time apparent be reduced to the mean (which in practice is called equating the time) it cannot be but that the calculation of the motions should for the most part differ considerably from the observation of them, and that the moments of time should be otherwise in the tables than they are according to our clocks; therefore, it seems requisite, that I should premise something in this section concerning this equation of time, which is so necessary in all astronomical calculations, which I shall endeavour to explain under the following propositions;

1. The entire revolutions of the equator of the earth, reckoned either as in themselves, or, which comes to the same thing, with respect to the fixed stars, are each of them isochronal, or performed in equal spaces of time exactly. Here, I must confess, that this is contrary to what some have asserted, and to what some of the most famous astronomers, formerly, have been prone to think; but there are two things which establish this proposition, to mention nothing else: First, the agreeableness of this even equatorial, or, which is the same, sydereal day, to the calculation of the celestial motions, with the absolute necessity of this supposition unto the performing any thing with accuracy and judgment in astronomical computations. Secondly, the true knowledge of

the nature of things; for it is a thing most evident in nature, that when any body is put in motion it will persevere in the same state, and retain also the same degree of celerity, unless it be hindered, or disturbed by some impressed force from elsewhere, or by a resisting medium, neither of which having place in the motion of the earth, it must continually retain that motion, and that degree of celerity with which it was first impelled by the Supreme Power that first formed it.

2. The solar day, or that space of time which is betwixt the apparent noon of one day, and the apparent noon next succeeding, is unequal, and sometimes greater, sometimes lesser, according to the various seasons of the year. This proposition is known to all, and is obvious to daily observation in the motion of pendulum clocks, which do most exactly measure the time. I shall not in this place trouble my readers in mentioning either those false and imaginary, or the remote and far-fetched causes which many have assigned for this inequality; but intend to give only the true and geometrical reasons of it, and those only which are becoming an astronomer.

Now these are taken in the general from the motion of the Sun, or Earth; the one apparent, the other real; and from the coincidence of the unevenness of the earth's annual motion with the equality of the diurnal: in which consideration of this matter there is a complication of causes in the present inequality, as I shall endeavour to illustrate in the two following propositions:

1. Since there is then a double cause of this inequality, which proceeds from a two-fold unequal tenor of the celestial motions; that is, the eccentricity of the orbit of the earth, and the oblique position of the equator to the ecliptic, we are first to observe, that if the annual orbit was indeed circular, and had the Sun in the centre, so that the distance of the Sun from the earth should be always the same, no cause of this inequality would be found in the figure of the earth's orbit: for then, supposing the year to contain 360 days, every day over and above the equal space of one revolution would have allotted to it the equal intervals of one degree. Now, if to equals you add equals, the wholes, 'tis evident, will be equal. The same may be said of any other number of days whereof the year might be supposed to consist; but in the elliptical orbit, where the quantity of the annual motion is unequal, and different in some days from what it is in others, the circumstance must necessarily be quite otherwise, since unequals being added to equals, must of consequence produce unequals; for instance, let us suppose the earth in its aphe-
 lion, then will it, by its slower motion, daily change its angular position to the Sun less than it doth in the perihelion, and consequently the angle will be less which it doth then make over and
 above

above its entire revolution, to be added to that revolution, that so the solar day may be completed; for the annual motion, which about the superior focus of the ellipse is always nearly equal, is considerably unequal with respect to the Sun in the inferior focus, and therefore an inequality must evidently be introduced into the natural day.

2. The other cause of this inequality is the oblique position of the equator to the ecliptic; for if the axis of the earth were always moved parallel to the axis of the ecliptic, and consequently the plane of the equator had coincided with that of the ecliptic, there would be nothing in the earth's position with respect to the ecliptic that might cause this inequality: but when the diurnal and annual motions are performed upon very different axes, then an inequality of days must necessarily take place by the general consent of astronomers; for in this case the Sun's longitude along the ecliptic, and the diurnal motion along the equator, which we call the Sun's right ascension, are both to be taken into the account, and unless every arch of the ecliptic answered to every equal arch of the equator, so that there was no difference betwixt the longitude of the Sun and his right ascension, which thing cannot be, there must, most evidently, an inequality of days arise from thence; as for example, let the longitude of the Sun in the ecliptic be one degree, his right ascension in the equator at that time must not by the doctrine of triangles exceed fifty-five minutes; now this defect of five minutes being turned into time, will give one third part of a minute, which space, how small soever it may seem in itself, yet when it is augmented for many days successively by an almost equal increase, will introduce an inequality in no wise to be neglected.

3. Now the first of these two causes, viz. the eccentricity of the annual orbit, which hath nothing common to it with the second, viz. the obliquity of the equator to the ecliptic, we must have recourse to the aphelion and perihelion of the earth for an equation of time answering to the quantity of eccentricity, which equation of time will be once in the year affirmative, and once negative: but the second of these two causes, which is evidently divers from the first, will give an equation of time equal to the difference betwixt the Sun's longitude in the ecliptic and his right ascension in the equator, and which being to be reckoned from the equinoxes to the solstices, and from the solstices to the equinoxes, is twice a year affirmative, and twice negative.

The entire equation, therefore, of solar days, which is every where necessary in astronomical computations, is not to be fetched from either of these causes single, or alone, but from the combination of both; for where both the equations are affirmative, or both negative, the absolute equation of time will arise from the

sum of them, which is to be added, or subtracted, according to the tenor and name of both the equations; and when one is affirmative, and the other negative, their difference is to be added, or subtracted, according to the sign of the greater. Now both these parts of the equation of time are calculated by astronomers for every degree of anomaly, and for every degree of the Sun's longitude in the ecliptic, and disposed in two several tables, with directions for adding and subtracting, as the case requires, so that at all times the true or equal time may be had; and from thence it appears, that the apparent time, or that shewn by the Sun, is but four days in the whole year the same with the mean, or equal time, shewn by a good clock, or watch, viz. about April 15th, June 17th, August 31st, and December 24th; also about the 3d of November the equation is greatest of all in the year, being then about 16': 11" clocks, being then so much slower than the Sun.

These things being premised, I now proceed to the astronomical calculations, which I shall endeavour to explain by precepts founded on the *Tabulæ Dunelmenses*.



S E C T I O N III.

To determine the true Longitude of the Sun for any given Moment of Time.

P R E C E P T I.

FROM the table of the radical mean places of the Sun, and the Sun's apogee for 1700, New, or Old Style, write out the radical mean place of the Sun, and the radical mean place of the Sun's apogee for the given month in two sums; also from the table of mean motions of the Sun and apogee for complete Julian years, write out the mean motion of the Sun and apogee for the years above 1700, and set them under the former numbers; then from table of mean motions of the Sun and apogee for days, hours, minutes, and seconds, take the mean motions answering to the given days, hours, minutes and seconds, each one in its order, in a double file of numbers, and in such wise that not only the signs and degrees, but minutes also, both first and second, be carefully noted and wrote down.

P R E C E P T

PRECEPT II.—Sum up all the mean motions of the Sun and apogee, both those of the radix itself, and those of complete years, together with those of the month, days, hours, minutes, and seconds, in two sums, so will you have the mean motion of the Sun, and also the mean motion of the Sun's apogee, in signs, degrees, minutes, and seconds, for the given time.

PRECEPT III.—From the mean motion of the Sun subtract the mean motion of the apogee, and you'll have the Sun's mean anomaly, which will be the foundation of all your future operations.

PRECEPT IV.—With the Sun's mean anomaly now found, enter table, intituled table of the equation of the Sun's center, and there look for the Sun's mean anomaly, which, as to the degrees of it, is on the left hand, if it be contained in the first six signs; but on the right hand if within the limits of the latter six signs; and the quantity of the equation answering to that anomaly, and this not only in whole degrees, which you have to your hand in the table, as also the minutes and seconds belonging to that anomaly, and are found out by making proportion for the odd minutes and seconds of anomaly above whole degrees, which having obtained, add or subtract this entire equation to, or from, the Sun's mean motion before found, and you'll have the Sun's true longitude in the ecliptic, according to mean or equal time.

PRECEPT V.—Having thus obtained the Sun's true longitude, and mean anomaly, enter table, intituled first equation of time, and take out the equation answering to the Sun's true longitude, making proportion for the minutes and seconds of anomaly above whole degrees, write down this equation, with the sign + or — according to the title in the table; then with the Sun's mean anomaly enter table second equation of time, and in like sort take out the second part of the equation of time, and write it under the first, with its sign also of + or — and then observe if both signs be +, or both, — the sum of the two equations must be added to, or subtracted from, the mean or equal time, in order to obtain the apparent time; but if one sign be + and the other — the difference of these two equations must be added to, or subtracted from, the mean or equal time, according to the sign of the greater of the two equations, and you will have the apparent time.

PRECEPT VI.—With the Sun's same mean anomaly enter the table, intituled, A table of the true hourly motions and diameters of the Sun, and take out the Sun's true hourly motion and diameter answering to that mean anomaly; and thus much for the precepts for finding the Sun's longitude, which I shall now illustrate by examples.

Required

Required the Sun's true longitude on the 24th of July, 1777, at 5 hours, 15 minutes, 30 seconds, A. M. (or morning.)

Me. Mot. ☉				Me. Mo. ☉ Apo.				
	S.	°	'	''	S.	°	'	''
July 1700, N. S.	3	8	31	40	3	7	43	57
Compl. } 76.			34	36		1	17	54
Years } 1.	11	29	45	40			1	1
Days 23.		22	40	12				4
Hours 17.			41	53				
Minutes 15.				37	3	9	2	56
Seconds 30.				1				
Sun's me. mo.	4	2	14	39	First equa. time	8	59	—
Apo—	3	9	2	56	Second ditto	3	1	+
Sun's me. ano.	0	23	11	43	Absolute equa.	5	58	—
Eq. Sun's cent.	—		44	45	D. H. M. S.			
Sun's true long.	4	1	29	54	Mean time, July	23	17	15 30
					Equation time	—		5 58
					App. time, July	23	17	9 32

Sun's hourly motion 2 23 diam. 31 40.

Let the true longitude of the Sun be required for the 12th of December, at 8 hours, 45 minutes, 52 seconds, P. M. (or afternoon) 1777.

	☉ me. Mo.				Me. Mo. Apo.			
	S.	°	'	''	S.	°	'	''
December, 1700, N. S.	8	9	19	54	3	7	44	23
Complete } 76.			34	36		1	17	54
Years } 1.	11	29	45	40			1	1
Days 12.		11	49	40				2
Hours 8.			19	43				
Minutes 45.				1 51	3	9	3	20
Seconds 52.				2				
Sun's mean motion	8	21	51	26				
Apogee —	3	9	3	20				
Sun's mean anom.	5	12	48	6				
Equation Sun's centre —			34	57				
Sun's true longitude	8	21	16	29				

First

	'	''		D. H. M. S.
First equation time	3	6	+	Mean time, Dec. 12 8 45 52
Second ditto	2	20	+	Equation + 5 26
Absolute equa. time	5	26	+	Apparent time 12 8 51 18
Hourly mean motion of the Sun	—	—	—	2 33
Sun's apparent diameter	—	—	—	32 41½

Lastly,—Let the Sun's true longitude be sought for the 28th of May, 5 hours, 54 minutes, 54 seconds, P. M. mean time, in the meridian of Sardis, in Asia, in the year ante Christum 585, Julian stile.

			H. M. S.
Mean time at Sardis	—	—	5 54 54
Difference of meridian between Sardis and Greenwich	1	56	00
Mean time at Greenwich	—	—	3 58 54

	S.	0	'	''	S.	0	'	''
Ante Christum 500	0	3	47	49	0	8	32	30
Complete } 84			38	15		1	26	6
Years } 1	O S.	11	29	45	40		1	1
Sun's me. mo. 585	0	4	11	35	0	9	59	37
May 1, year Christ.	1	6	6	19	2	8	42	20
Sun's mean motion	1	1	54	44	1	28	42	43
Days 28		27	35	53				5
Hours 3			7	24				
Minutes 58			2	23	1	28	42	48
Seconds 54				2				

Sun's mean motion	1	29	40	26
Apogee —	1	28	42	48

Sun's mean anom.	0	0	57	38
------------------	---	---	----	----

Equa. Sun's centre —			1	54
----------------------	--	--	---	----

Sun's longitude	1	29	38	32
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SECTION

S E C T I O N IV.

To find the true Place of the Moon, both in Longitude and Latitude, for any given Moment of Time.

P R E C E P T I.

BY the former section obtain both the true place of the Sun and the mean anomaly of the same, together with both parts of the equation of time, and from thence the absolute equation of time, without which you cannot proceed in your calculation; therefore, you ought to be very expert in finding the Sun's place, upon which the lunar inequalities do for the most part depend; nor is the knowledge of the Sun's mean anomaly less necessary; and as for the equation of time, so necessary every where, and here especially, as you'll be under an absolute necessity at the beginning of your work, if the time given be the apparent time, to reduce, or equate the same to mean or equal time, all the tables of the mean motions being accommodated to the mean time.

PRECEPT II.—Out of the table of the radical mean places and motions of the Moon, apogee, and node, for 1700, Gregorian, or New Style, and on a line with the given month, take the mean motion of the Moon, apogee, and node, and write them down in a treble file of numbers, and in such wise, that not only the signs and degrees, but minutes and seconds, be carefully noted and wrote down: also from table of the mean motions of the Moon, apogee, and node, for 99 Julian years, write out the mean motions of the Moon, apogee, and node, for complete years above 1700, noting them down under the former numbers: from table of mean motions of the Moon, apogee, and node, for days, take out the mean motions for the given days of the month: lastly, from table of the mean motions of the Moon, apogee, and node, for hours, minutes, and seconds, write out the mean motions for the given hours, minutes, and seconds; collect all these together, with the mean motions of the radical year, (as before directed in treating of the Sun) into two sums, one of the Moon's mean motion, the other of the mean motion of the Moon's apogee. As for the node, its motion as to the complete years, months, days, hours, minutes, and seconds, are to be wrote out as above directed; but seeing the motion of the nodes is contrary to the mean motions of the Moon and apogee, as being in antecendentia, or retrograde, the numbers for the complete years above 1700, together with the month,

month, days, hours, &c. are not to be added to the motion for the radical years, but to be subtracted therefrom, in order to obtain the mean place of the node ascending for the given time.

PRECEPT III. Having thus obtained the mean motion of the Moon, apogee, and node, for the given time, our next business will be to equate the same; in order thereto, enter table I. equation of the Moon, or annual equation, with argument Sun's mean anomaly, take out the first equation of the Moon, apogee, and node, which being added to, or subtracted from, the mean motion of the Moon, apogee, and node, according to their title in the table, we shall have the Moon's place, as also the place of the apogee and node once equated.

PRECEPT IV.—From the Moon's place once equated subtract the place of the apogee once equated, the difference will shew the Moon's mean anomaly.

PRECEPT V.—From the true longitude of the Sun subtract the Moon's apogee once equated, and call the remainder Sun from the Moon's apogee, with this argument; enter table II. equation of the Moon, or I. semi-annual, and take out the equation answering thereto, with its sign +, or —, and set it down with its sign. From the Sun's true longitude take the Moon's node once equated, call the difference Sun from the Moon's node, with which enter table III. equation Moon, and take out the equation answering thereto, with its sign +, or —, noting it down, with its sign; from twice the Sun from the Moon's node, or double the last argument, take the Sun from the Moon's apogee, with the residue, enter table IV. equation of the Moon, taking out the equation answering thereto, and note it down, with its sign +, or —; from the Moon's mean anomaly take the double of the Sun from the Moon's apogee, and call the difference the mean evection. To this same mean evection add the double of the Moon's mean anomaly, with the sum enter table V. equation of the Moon, and take out the equation thereto belonging, note it down, with its sign +, or —. To the mean evection add the Sun's mean anomaly, enter table VI. equation of the Moon, and take out its corresponding equation, noting it down, with its sign +, or —. Lastly, from this same mean evection subtract the Sun's mean anomaly, and with the difference enter table VII. equation of the Moon, and write out the equation answering thereto, with its sign +, or —, add the affirmative equations into one sum, and the negative equations into another, and subtract the lesser sum from the greater, the difference, whether affirmative or negative, added to, or subtracted from, (according to its sign +, or —) the Moon's mean anomaly will give the Moon's corrected anomaly, or anomaly seven times equated.

PRECEPT VI.—With the Moon's corrected anomaly enter table VIII. mean ecliptic equation of the Moon's centre, and take out
D the

the central equation belonging thereto, (making proportion for the odd minutes and seconds above whole degrees in the anomaly) and according to its sign +, or —, add it to, or subtract it from, the Moon's anomaly seven times equated, and you'll have the Moon's anomaly eight times equated.

PRECEPT VII.—To or from the mean evection, add or subtract $\frac{1}{2}$ the central equation just found, the sum, or difference, will give you the argument of evection, with which enter table IX. evection equation of the Moon, or second equation of the Moon's centre, taking out the equation answering thereto, which, according to its title +, or —, being added to, or subtracted from, the Moon's anomaly eight times equated, will give you the Moon's anomaly nine times equated.

PRECEPT VIII.—From the Moon's anomaly nine times equated take the Sun from the Moon's apogee, call the remainder Moon from the Sun, with this argument enter table X. or compound variation-equation of the Moon, take out the equation answering thereto, with its sign +, or —, with the same argument, viz. Moon from the Sun, enter the table, intituled the equation of mean variation of the Moon in octants, or mean distance from the Sun, to variation in perigee and apogee Sun from the earth, and take out its equation +, or —; also with the Sun's mean anomaly enter table, intituled correction of mean variation, and take out the decimal multiplier, with which multiply the last found equation, cutting off two figures to the right hand, the remaining figures on the left hand will be so many seconds. Now, if this and the first found equation be both affirmative, or both negative, their sum added to, or subtracted from, the Moon's anomaly nine times equated, will give you her anomaly 10 times equated: but if one be affirmative, and the other negative, the difference added to, or subtracted from, according to the sign of the greater, will give you the same.

PRECEPT IX.—To the Moon's anomaly, 10 times equated, add the Moon's apogee once equated, the sum will give you the Moon's true place in her orbit.

PRECEPT X.—From the Moon in her orbit subtract the node once equated, the remainder will be the argument of latitude, or Moon in her orb; from the node once equated, with this argument, enter table XI. called mean reduction equation of the Moon to the ecliptic, and take out its corresponding equation, which, according to its title, added to, or subtracted from, the Moon in her orbit, will give you her place, or true longitude, in the ecliptic.

PRECEPT XI.—With this same argument of latitude take from table Moon's mean latitude at mean inclination of her orbit, the Moon's mean latitude answering thereto; and observe if the argument

argument of latitude be 0 signs, 1 sign, or 2 signs, the mean latitude is North, ascending, or increasing, and marked N. A. Also if the argument of latitude be 6 signs, 7 signs, or 8 signs, the mean latitude is marked S. A. which signifies South ascending, or increasing.

But if the argument of latitude be 5, 4, or 3 signs, then is the mean latitude ND, or North, descending, or decreasing. Lastly, if the argument of latitude be 11, 10, or 9 signs, the mean latitude is SD, or South, descending, or decreasing. Having thus obtained the mean latitude, whether NA, ND, SA, or SD, note it down accordingly; from the double of the Moon from the Sun take the argument of latitude, with the remainder enter the table, intituled, equation of the Moon's mean to her true latitude for the present inclination of her orb, and take out the equation answering thereto. Now, if both these equations be NA, ND, or both, SA, SD, their sum, otherwise their difference will be the Moon's latitude, N, or S, once equated. From the first equation subtract the Sun's mean anomaly, and with the residue enter table III. equation of the Moon to her true latitude for the present from the mean inclination of her orb, and take its corresponding equation, which if it be of the same tenor, or name, with the other two, add, otherwise subtract, the sum, or the difference, will be the Moon's true latitude sought.

PRECEPT XIII.—In order to obtain the true hourly motion of the Moon both in latitude and longitude, repeat the operation for one hour before the given time, or one hour after, as occasion shall require, taking the lesser number from, or out of the greater, you'll gain your end.

PRECEPT XIII.—Enter table mean horizontal parallax of the Moon, with the Moon's mean anomaly seven times equated, and take out her mean horizontal parallax answering thereto, making proportion for the odd minutes and seconds of anomaly; if need require. With the mean evection, as an argument, take out from table I. equation of the Moon's horizontal parallax the proper equation, with its sign +, or —, and add to, or subtract from, Moon's mean horizontal parallax, will give you her parallax once equated. Lastly, with argument Moon from the Sun, take from table II. equation of the Moon's horizontal parallax the equation corresponding with its sign +, or —, which, according to its sign, add to, or subtract from, the Moon's horizontal parallax once equated, and you will thence obtain her true horizontal parallax.

PRECEPT XIV.—Since it has been proved that the Moon's horizontal parallax is at all times to her horizontal diameter as 11 to 6, her apparent horizontal diameter, and consequently her apparent semi-diameter will be known.

And thus, with sufficient care and labour, we may obtain the Moon's longitude and latitude, together with all the other requisites in the lunar orb.—(See examples).

Required the true longitude and latitude of the Moon on the 24th of July, 5 hours, 15 minutes, 30 seconds, A. M. or the 23d day, 17 hours, 15 minutes, 30 seconds, P. M. 1777, mean time.

	☽ me. Mot.				☽ Apogee ☽				☽ Node			
	S.	°	'	"	S.	°	'	"	S.	°	'	"
July, N. S. 1700	8	25	57	21	10	16	33	32	5	7	44	4
Comp. Years } 76.	3	33	31		7	2	34	57				
1.	4	9	23	3	1	10	39	50		29	58	57
Days	23	10	3	3	26		2	33	45	19	19	43
Hours	17		9	20	0		4	44		1	13	5
Minutes	15			8	14			4			2	15
Seconds	30.			16								2
						7	2	26	52			
Moon's me. mo.	11	21	25	51		—	10	2		1	20	34
First equa. +			4	22								
						7	2	16	50		3	17
☽ 1 eq.	11	21	30	13							+	3
Apogee	7	2	16	50								37
										3	17	13
☽ me. anom.	4	19	13	23								39
6 lefs equa. —				2	32							
☽ Anom. 7 eq.	4	19	10	51								
Central equa. —			4	20	44							
☽ Anom. 8 eq.	4	14	50	7								
Eveft. equa. +				52	34							
☽ Anom. 9 eq.	4	15	42	41								
Variation +			41	6								
☽ Anom. 10 eq.	4	16	23	47								
Apo. +	7	2	16	50								
☽ in her orb.	11	18	40	37								
☾ —	3	17	13	39								
Arg. lat.	8	1	26	58								
Reduc. —			5	52								
☽ in the ecliptic	11	18	34	45								
☽ true lat.	4	35	22		S. A.							

	'	+	"	—
2	—	21		
3	—	—	—	22
4	—	52		
5	—	—	1	13
6	—	—	—	40
7	—	—	1	30
	1	13	3	45
		+	1	13
	—	—	2	32

Sun's

	S.	°	'	"		S.	°	'	"
Sun's true longitude, see page 14	-	-	4	1	29	54			
Mon's apogee & equated subtract	-	-	7	2	16	50			
Sun from Moon's apogee, ☉ a' ☽ apogee			8	29	13	4			
Sun's longitude	-	-	4	1	29	54			
Moon's node subtract	-	-	3	17	13	39			
Sun from the Moon's node ☉ a' ☽ Ω	-		0	14	16	15			
2 ☉ a' ☽ Ω	-	-	0	28	32	30			
☉ a' ☽ apogee subtract	-	-	8	29	13	4			
Argument 4th equation	-	-	3	29	19	26			
	S.	°	'	"		S.	°	'	"
☽ mean Anomaly	4	19	13	23	2 ☽ a' ☉	3	2	59	14
2 ☉ a' ☽ apo. —	5	28	26	8	Argum. lat. —	8	1	26	58
Mean evection	10	20	47	15	2d argum. lat.	7	1	32	16
Mean evection	10	20	47	15	First equa. ☽ lat.	0	4	30	54
2 ☽ me. anom. +	9	8	26	46	☉ mean anom. —	0	23	11	43
Argum. 5th equa.	7	29	14	1	3d arg. lat.	11	11	19	11
Mean evection	10	20	47	15					
☉ me. anom. +	0	23	11	43	☽ horizontal parallax	58	56		
Argum. 6th equa.	11	13	58	58					
Mean evection	10	20	47	15	As 11:6::58 56:32 8 ☽ diam.				
☉ mean anom. —	0	23	11	43					
Argum. 7th equa.	9	27	35	32	Whence ☽ semi-diameter	16	4		
Mean evection	10	20	47	15					
½ central equa. —	2	10	22		☽ simple lat.	4	30	54	S A.
Argum. 9th equa.	10	18	36	53	2 equation	4	37	S A.	
☽ anom. 9 eq.	4	15	42	41	☽ equated lat.	4	35	31	S A.
☉ a' ☽ apogee —	8	29	13	4	3 equation	9	N.		
Argum. 10th eq.					☽ true lat.	4	35	22	S A.
or ☽ a' ☉	7	16	29	37					

Required

Required the true longitude and latitude of the Moon on the 12th of December, at 8 hours, 45 minutes, 52 seconds, mean time, P.M. 1777.

	☽ me. Mo.	Me. Mo. ☽ Ap.	Me. Mo. ☽ Ω
	S. ° ' "	S. ° ' "	S. ° ' "
December 1700	4 1 56 40	11 3 36 15	4 29 37 57
Comp. } 76.	3 33 31	7 2 34 57	
Years } 1.	4 9 23 3	1 10 39 50	22 58 57
Days 12.	5 8 7 0	1 20 13	19 19 43
Hours 8.	4 23 32	2 14	38 8
Minutes 45.	24 42	12	1 4
Seconds 52.	29	1	5
			1
☽ me. mo.	1 27 48 57	7 18 13 42	
☽ equa.	+ 3 29	- 7 51	1 19 57 58
☽ 1 eq.	1 27 52 26	7 18 15 51	3 9 39 59
Apo. —	7 18 5 51		+ 2 49
☽ me. anom.	6 9 46 35		3 9 42 48
6 lefs eq. —	8 24		
☽ an. 7 eq.	6 9 38 11	☉ a' ☽ apogee	1 3 10 38
Cent. eq. +	1 6 6	2 ☉ a' apogee	2 6 21 16
☽ an. 8 eq.	6 10 44 17	☉ a' ☽ Ω	5 11 33 41
Evect. —	1 7 15	2 ☉ a' ☽ Ω	10 23 7 22
☽ an. 9 eq.	6 9 37 2	Mean evection	4 3 25 19
Varia. —	27 24	☽ a' ☉	5 6 26 24
		2 ☽ a' ☉	10 12 52 48
☽ an. 10 eq.	6 9 9 38		
Apo. +	7 18 5 51		
☽ in orb.	1 27 15 29		
Ω —	3 9 42 48		
Arg. lat.	10 17 32 41		
Reduc. +	6 57		
☽ long.	1 27 22 26		
☽ lat. —	3 28 36 S. D.		

	' + "	' — "
2	— —	5 24
3	— 29	— 56
4	— —	— —
5	— 51	— —
6	— —	2 19
7	— —	1 5
+	1 20	9 44
	+	1 20
	—	8 24

Required

Required the longitude and latitude of the Moon on the 28th of May, 3 hours, 58 minutes, 54 seconds, P. M. mean time, at Greenwich, 585 ante Christum, Julian stile.—(See page 15.)

	S. ° D' "	S. Apo. ' "	S. ° Ω' "
500 A. C.	3 9 12 5	6 5 56 15	10 10 56 15
84.	11 14 59 9	5 28 7 3	6 4 43 3
1.	4 9 23 3	1 10 39 50	19 19 43
585.	7 3 34 17	1 14 43 8	5 4 59 1
1st year Christ	8 23 14 8	9 25 27 53	8 22 14 28
☽ me. mo.	1 19 39 51	8 10 44 45	1 27 13 29
May 28 days	8 56 21	3 7 10	
Hours 3.	1 38 49	50	1 28 58
Minutes 58.	31 50	16	24
Seconds 54.	30		7
☽ me mo.	2 0 47 21	8 13 53 1	1 29 29
1st equa. +	11	— 25	
☽ 1 eq.	2 0 47 32	8 13 52 36	1 25 44 0
Apo. —	8 13 52 36		+ 10
☽ me. ano.	5 16 54 56		1 25 44 10
6 less eq. +	1 37		S. ° / "
☽ ano. 7 eq.	5 16 56 33	☉ a' ☽ apogee	5 15 45 56
Cent. equ. —	1 24 45	2 ☉ a' ☽ apogee	11 1 31 52
☽ ano. 8 eq.	5 15 31 48	☉ a' ☽ Ω	0 3 54 22
Evect. +	20 40	2 ☉ a' ☽ Ω	0 7 48 44
☽ ano. 9 eq.	5 15 52 28	Mean evection	6 15 23 4
Vari. +	6	☽ a' ☉	0 0 6 32
☽ ano. 10 eq.	5 15 52 34	2 ☽ a' ☉	0 0 13 4
Apo. +	8 13 52 36		
☽ in orb.	1 29 45 10		
Ω —	1 25 44 10		
Arg. lat.	0 4 1 0		
Reduc. —	58		
☽ long.	1 29 44 12		
☽ lat.	20 59 N. A.		

	' + "	' — "
2	2 35	— —
3	— —	— 7
4	— —	— 22
5	— 17	— —
6	— —	— 22
7	— —	— 24
+	2 52	1 15
—	1 15	— —
+	1 37	— —

SECTION

S E C T I O N V.

*To find the Time of the true ecliptic Conjunctions
and Oppositions of the Sun and Moon.*

P R E C E P T I.

TAKE out of the table of the mean motions of the Moon from the Sun the numbers ascribed to the radical year the complete years from thence, and the beginning of the given month; and having gathered them all into one sum, subtract that sum out of the whole circle, or twelve signs: the remaining numbers of themselves, if the conjunction be that which you seek, and the same increased by six signs, if the opposition be sought, will, when turned into time; give the mean moment of the conjunction, or opposition, nearly; that is to say, if first amongst the mean motions belonging to days you subtract the number which is the next less to the given one out of the given one, and then seeking the remainder amongst the mean motions belonging to hours, you do as you did before; that is, take out the next less to the said remainder, and subtract it out of the remainder; and afterwards, if you seek the last remainder amongst the mean motions belonging to minutes, and writing out the next less to the same, you take this next less in like manner out of the remainder; and then, lastly, if seeking the last remainder amongst the mean motions belonging to seconds, you write out the seconds belonging to the same; if you do thus, that day, with the hours, minutes, and seconds, will shew you the near time of the mean conjunction, or opposition, if the year be not bissextile; if it be, the day next less to the given one, with the hours, minutes, and seconds, which you have before found, will be the near mean time required. Now, having this near mean or equal time given, we may easily find the true time of the mean conjunction, or opposition, by the following:

PRECEPT II.—Calculate the longitude of the Sun and of the Moon in the ecliptic by the precepts in the 3d and 4th sections; then, if the places of these luminaries agree in longitude, so that they are defined by the very same numbers, (which, however, happens but very rarely) or if their places be diametrically opposite to each other, then the conjunction, or opposition, will happen at the very same time; but if, as it commonly happens, the longitude of the Moon be greater, or lesser, than that of the Sun, take the difference; for by that difference you may obtain the true conjunction, or opposition, in this manner:

PRECEPT

PRECEPT III.—To one hour before, or one hour after, the mean time of conjunction, or opposition, according as the Moon is in antecedentia, or consequentia, of the Sun: compute again the places of the Sun and Moon, by which you will gain the true hourly motion of the Moon, as also the true hourly motion of the Sun; then from the true hourly motion of the Moon take the true hourly motion of the Sun, and you'll have the true hourly motion of the Moon from the Sun; then work by the golden rule, saying, as the hourly motion of the Moon from the Sun is to one hour, so is the difference of longitude of the Moon and Sun to the interval of the mean and true conjunction, or opposition; which interval of time, if the Moon hath not yet overtaken the Sun, superadded to the mean time, gives the time of the true conjunction, or opposition; but if the Moon have already passed the Sun, taken from that time will shew the mean moment of the true conjunction, or opposition. To this time compute again the true places of the Sun and Moon, and if they agree exactly to the same second in respect to longitude, or if their places be diametrically opposite, or differ precisely six signs in longitude, then have you got the true time of conjunction, or opposition; otherwise you must proportion again, and continue your computation until you get an exact agreement, as will be exemplified further on.

PRECEPT IV.—Having thus obtained the mean or equal time of the true conjunction, or opposition, our next business will be to equate the mean to the apparent time. Thus, by section III. seek the equation of apparent time depending on the Sun's true place, as also that part of the equation which belongs to the Sun's mean anomaly, and from thence the absolute equation of time, as is there taught: which having found, add it to, or subtract it from, (according to its sign +, or —) the mean conjunction, or opposition, and you'll thereby obtain the apparent time of the ecliptic conjunction, or opposition, according to the meridian of your tables.

S E C T I O N VI.

To find in any year how many Eclipses there will be, and in what Months they happen.

IN order to discover how many eclipses will happen in any year, we are first to observe, that the Sun enters the twelve zodiacal signs on these days, as under:

♈	♉	♊	♋	♌	♍	♎	♏
January,	February,	March,	April,	May,	June,	July,	August,
20	18.	20.	20.	21.	21.	23.	23.
♐	♑	♒	♓	♈	♉	♊	♋
September,	October,	November,	December:				
23.	23.	22.	21.				

Find for the given year the mean place of the Moon's North node; for in those months in which the Sun enters the signs that the lunar nodes are in, will the eclipses of the luminaries happen for that year; and the nodes being diametrically opposite, if there happen an eclipse in January, there will also one happen in July, seeing the signs, Aquarius and Leo, are opposite signs, and are those into which the Sun makes his ingress in January and July, which may therefore be called the node months.

By section 5th find the mean new and full Moons in the node months, as also in the months next before and after the node months, (by which means you will be sure not to miss any eclipse for that year.) Set down the longitude of the Moon, both at new and full, in two several places, and from these places severally subtract the place of the Moon's North node for each new and full Moon in each node month, calling the remainders the argument of latitude, which if it be less than the limits of eclipses found in section 1st, there will be an eclipse at that time, otherwise none.

Having thus far dispatched the doctrine of eclipses, wherein I have endeavoured all along to render every particular as conspicuous and as easy as I possibly could, shall in the ensuing part of this work strive to make the mode of calculation as familiar as the subject will admit.

Let

Let it be required to find how many eclipses of the Sun and Moon will happen in the year 1777, and in what months.

THE year 1777 is the first after biffextile, or leap year, the epact is 20, and the radical place of the lunar node is $\alpha 26^{\circ}$: $13': 38''$ at the beginning of the year, and consequently do not change its sign that year; whence the months in which the eclipses are likely to happen, are January, February, July, November, and December: it will here be necessary to examine the lunations in the month before, and in the month after, the node months, that no eclipse be missed. Therefore, by precept 1st, section 5, find the mean conjunctions, and also the mean oppositions of the Sun and Moon, in January, February, June, July, November, and December, and from thence the true conjunctions, and true oppositions; which having obtained, proceed according to the foregoing precepts in this section, and as in the following examples:

But I shall first give an example of finding the mean conjunction and opposition of the Sun and Moon in January, 1777, as under:

				Me. Mo. Δ a' $\odot$			
				S.	o.	'	''
January	1700	-	-	4	0	54	10
Complete years	76	-	-		2	58	55
	1	-	-	4	9	37	23
Subt.	1777	-	-	8	13	30	28
From the whole circle		-	-	12	—	—	—
Remain motion Δ a' $\odot$		-	-	3	16	29	32
Days 8		-	-	3	7	31	33
Remain		-	-	8	57	59	
Hours 17		-	-	8	38	6	
Remain		-	-		19	53	
Minutes 39		-	-		19	48	
Remain		-	-			5	
Seconds 10		-	-			5	
				D. H. M. S.			
Mean conjunction, January				8	17	39	10, 1777.

(28)

		S.	°	'	"
Motion Moon from the Sun	-	3	16	29	32
Add a semi-circle	-	6	—	—	—
Sum	-	9	16	29	32
Days 23	-	9	10	23	13
Remain	-	6	6	19	
Hours 12	-	6	5	43	
Remain	-				36
Minutes 1, seconds 12	-				36

D. H. M. S.

Mean opposition, January 23 12 1 12, 1777. This is so very easy, that more examples would doubtless be deemed unnecessary: therefore, having thus obtained the mean conjunctions and oppositions, you may proceed according to the other precepts in section 5th, to find the true, as I shall exemplify further on, and proceed now to examine the node months :

	D. H. M. S.	S.	°	'	
New ☽ January 9 2 14 38 ☽ in		9	19	47	☉ Eclipse. 1.
North ♀ subtr.	-	3	27	40	
Argument of latitude	-	5	22	7	
Within the limit Sun eclipsed, visible.					

	D. H. M. S.	S.	°	'	
Full ☽ January 23 4 54 41 ☽ in		4	4	9	☽ Eclipse. 2.
North ♀ subtr.	-	3	26	4	
Arg. lat.	-	0	8	5	
Within the limit Moon eclipsed, visible.					

	D. H. M.	S.	°	'	
New ☽ February 7 15 47 ☽ in		10	19	49	
North ♀ subtr.	-	3	25	57	
Argument of latitude	-	6	23	52	
Past the limits no eclipse.					

	M. H. M. S.	S.	°	'	"
New ☽ June 5 3 50 35 ☽ in		2	15	10	20
North ♀ subtr.	-	3	19	41	0
Argument of latitude	-	10	25	29	20
Past the limits no eclipse.					

Fall

	D.	H.	M.	S.	S.	°	'	"
Full ☽ June	20	12	9	58	☽ in	8	29	45
North ♀ subt.						3	18	56

Argument of latitude - - - 5 10 49
 Past the limits no eclipse.

	D.	H.	M.	S.	S.	°	'	"
New ☽ July	4	11	7	3	☽ in	3	13	7 32
North ♀ subt.						3	18	11 38

Argument of latitude - - - 11 24 55 54 } 31
 Within the limit Sun eclipsed, invisible.

	D.	H.	M.	S.	S.	°	'	"
Full ☽ July	19	22	19	11	☽ in	9	27	42 48
North ♀ subt.						3	17	24 55

Argument of latitude - - - 6 10 17 53 } 4.
 Within the limit Moon eclipsed, invisible.

No eclipse in November.

	D.	H.	M.	S.	S.	°	'	"
Full ☽ December	13	13	59	11	☽ in	2	17	38 40
North ♀ subt.						3	9	35 42

Argument of latitude - - - 11 8 2 58 }
 Past the limit no eclipse.

	D.	H.	M.	S.	S.	°	'	"
New ☽ December	29	7	7	33	☽ in	9	8	33 57
North ♀ subt.						3	8	47 19

Argument of latitude - - - 5 29 46 38 } 5.
 Within the limit Sun eclipsed, invisible.

Thus, having examined all the mean new and full Moons in every month in which it is possible for an eclipse to happen, I find that in the course of the year 1777 there will be five eclipses of the luminaries, viz. three of the Sun, and two of the Moon, in the following order: the first will be a solar eclipse, on the 9th of January, P. M. and visible only at the beginning. The second will be a lunar eclipse, on the 23d of January, P. M. when the Moon will rise eclipsed. The third will be a solar eclipse, on the 4th of July, near midnight. The fourth a lunar eclipse, on the 20th of July, A. M. and therefore invisible. The fifth and last a solar eclipse, on the 29th of December, about seven at night.

SECTION

S E C T I O N VII,

To find the Moments, Duration, and the Rest of the Affections of Lunar Eclipses.

IN computing a lunar eclipse, at the time of the true ecliptic opposition of the Sun and Moon, find the angle which the visible way of the Moon from the Sun make with the ecliptic, which is thus obtained : say,

As S. of the argument of the $\mathcal{D}$ lat.
 To Radius,
 So is S. of the $\mathcal{D}$ lat.
 To S. of an angle, which call A, and say again,
 As log. of the hourly motion $\mathcal{D}$ a' $\odot$ co. ar.
 To log of the hourly motion of the $\mathcal{D}$
 So is S. of the angle A.
 To S. angle visible way of the $\mathcal{D}$ with the ecliptic.

Having thus obtained the angle of the visible way of the $\mathcal{D}$ with the ecliptic, our next business will be to find the nearest approach of the centres of the Moon and the Earth's shadow, which may be found according to the following analogy: say,

As radius
 To S. $\mathcal{D}$ latitude,
 So is Sc. angle $\mathcal{D}$ way with the ecliptic
 To S. of the nearest approach centres.

Increase the apparent semi-diameter of the earth's shadow by 50" for the earth's atmosphere. From the sum of the semi-diameters of the Moon and earth's shadow, subtract the nearest approach of the centres of the Moon and earth's shadow, the remainder will be the parts deficient: then say, as the semi-diameter of the Moon to six digits, so are the parts deficient to the digits eclipsed. From the square of the sum of the semi-diameters of the Moon and the earth's shadow in seconds, deduct the square of the nearest approach of the centres of the Moon and earth's shadow in seconds, the square root of the difference will be the motion of semi-duration in seconds.

If the eclipse be discovered to be above 12 digits, (or total) then from the square of the difference of the semi-diameters of the Moon and earth's shadow in seconds, deduct the square of the nearest approach of the centres of the Moon and earth's shadow
 in

in seconds, the square root of the remainder will be the motion of semi-duration in total darkness in seconds.

Then say, as the hourly motion of the Moon from the Sun (reserved in finding the true opposition) is to one hour, so is the motion of semi-duration in seconds to the time of semi-duration, and so is the motion of semi-duration in total darkness to the time of ditto.

For the time of reduction say, as the hourly motion of the Moon from the Sun is to one hour, (or 3600 seconds) so is the reduction to the time of reduction. This time of reduction being doubled, and applied to the apparent time of the ecliptic opposition, according to its first title +, or —, will give the apparent time of the middle of the eclipse.—For an illustration of this section see the following examples :

A calculation of the mean opposition of the Sun and Moon for a lunar eclipse on the 23d of January, 1777, in the meridian of Greenwich.

	S.	°	'	"		S.	°	'	"
January	1790	9	10	7 32		3	7	43	27
Comp. years	76			34 36		1	17	54	
	1	11	29	45 40				1	1
Days	23		22	40 12					4
Hours	4			9 51					
Minutes	42			1 43		3	9	2	26
Seconds	20			1					
☉ me. mo.	10	3	19	35	Hourly motion ☉	32	3		
Apog. —	3	9	2	26	Ditto ☉		2	32	
☉ me. anom.	6	24	17	9	Hourly mo. ☉ a' ☉	29	31		
Equa. +			48	33					
☉ longitude	10	4	8	8					
First equation of apparent time	-	-	-	-		9	20	—	
Second ditto	-	-	-	-		3	13	—	
Absolute equation of apparent time	-	-	-	-		12	33	—	
Hourly motion of the Sun	-	-	-	-		2	32		
Sun's semi-diameter	-	-	-	-		16	20		
Horizontal parallax of the Sun	-	-	-	-			9		

A calcu-

	S. ° ' "	S. ° ' "	S. ° ' "
January 1700	1 11 1 42	9 26 23 38	5 17 19 10
Comp. Years } 76.	3 33 31	7 2 34 57	
1.	4 9 23 3	1 10 39 50	29 58 57
Days	23. 10 3 3 26	2 33 45	19 19 43
Hours	4. 2 11 46	1 7	1 13 5
Minutes	42. 23 3	12	32
Seconds	20. 11		5
☽ me. mo.	3 29 36 42	6 12 13 29	1 20 32 22
1 eq. —	4 49	+ 10 52	
☽ 1 equat.	3 29 31 53	6 12 24 21	3 26 46 48
Apogee—	6 12 24 21		— 3 54
☽ me. anom.	9 17 7 32		3 26 42 54
6 lefs eq.	— 2 40		
☽ anom. 7 eq.	9 17 4 52	☉ a' ☽ ap.	3 21 43 47
Cent. eq.	+ 5 54 0	2 ☉ a' ☽ ap.	7 13 27 34
☽ anom. 8 eq.	9 22 58 52	☉ a' ☽ Ω	6 7 25 14
Evect. —	1 13 22	2 ☉ a' ☽ Ω	0 14 50 28
☽ anom. 9 eq.	9 21 45 30	Mean evect.	2 3 39 58
Variation +	4	☽ a' ☉	6 0 1 43
☽ anom. 10 eq.	9 21 45 34	2 ☽ a' ☉	0 0 3 26
Apo. +	6 12 24 21		
☽ in orb.	4 4 9 55	2 ' + " — "	
Ω —	3 26 42 54	3 3 24 — 11	
Arg. lat.	0 7 27 1	4 1 —	
Reduc. —	1 47	5 1 24	
☽ long.	4 4 8 8	6 2 25	
Lat.	38 36 N.A.	7 1 4	
		— 6 4	
		+ 3 24	
		— 2 40	

☽ horizontal parallax 56 13 semi-diameter 15 20
☽ true hourly motion 32 3 ditto in lat. 3 50

A Calculation of a Lunar Eclipse that will happen on Thursday, January 23, P. M. 1777, for the meridian of the city of Norwich. Lat. $52^{\circ}:45'$ North long. $1^{\circ}:15'$ East from Greenwich:

	H.	M.	S.
Ecliptic 8 mean time at Greenwich, Jan. 23, at	4	42	20
Difference of meridians +		5	—
Ecliptic 8 mean time at Norwich	4	47	20
Equation of apparent time —		12	33
Ecliptic 8 apparent time at Norwich	4	34	47
Double reduction in time —		7	14
Middle of the eclipse apparent time	4	27	33
Horizontal parallax Moon		56	13
Ditto of the Sun +			9
Sum		56	22
Semi-diameter of the Sun —		16	20
Semi-diameter of the earth's shadow		40	2
Atmosphere +			50
Semi-diam. of the shadow of the earth and atmosphere		40	52
Semi-diameter of the Moon +		15	20
Sum		56	12
Nearest approach centres Sun and Moon —		38	25
Parts deficient		17	47
Digits eclipsed	6 ^o :	57	31
Motion of semi-duration			2461
	H.		"
Time of ditto	1	23	22

For the reduction in time.

As $29':31''$ (1771'') to 1 hour (3600'') so is reduc. $1'-47''$ (107'')

To time of reduction $217''=3':37$ doubled is $7':14''$.

For the nearest approach centres

As radius	10.00000
To S. $38':36''$ D latitude	8.05027
So is Sc. $5^{\circ}:23:42''$ angle D way	9.99806
To S. $38':25''$ nearest distance centres $\odot$ and D	8.04833

For the angle of the visible way D with ecliptic

As S. $7^{\circ}:27':1''$ argument Moon latitude	9.11282
To radius	10.00000
So is S. $38':36''$ D latitude	8.05027
To S. $4^{\circ}:58':2''$ angle A.	8.93745

E

As

As 1771" hourly motion $\mathcal{D}$ a' $\odot$ co. ar. 6.75178
 To 32': 3" (1923") hourly motion $\mathcal{D}$ 3.28398
 So is S. 4°: 58': 2" angle A. 8.93745

To S. 5°: 23': 42" Angle visible way $\mathcal{D}$ 8.97321

As semi-diameter $\mathcal{D}$ 15': 20" (920") to 6 digits, so is parts deficient 17': 47" (1067") to $1067 \times 6 \div 920 = 6^\circ: 57': 31''$ the digits eclipsed.

Sum semi-diameter $\mathcal{D}$ earth's shadow 56': 12".

Or 3372", but $3372 \times 3372 = 11370384$.

Nearest approach of centres 38': 25", or 2305".

Then $2305 \times 2305 = 5313025$.

But $11370384 - 5313025 = 6057359$.

Whence $\sqrt{6057359} = 2461''$ the motion of semi-duration. For the time of ditto say, as hourly motion $\mathcal{D}$ a' $\odot$ 29': 31" (1771") to one hour (3600") so is 2461" to $2461'' \times 3600'' \div 1771'' = 5003 = 1$ H. 23 M. 22 S. the time of semi-duration.

	H.	M.	S.
Apparent time of the middle	4	27	33
Time of semi-duration — and +	1	23	22
Beginning of the eclipse	3	4	11
End of ditto	5	50	55

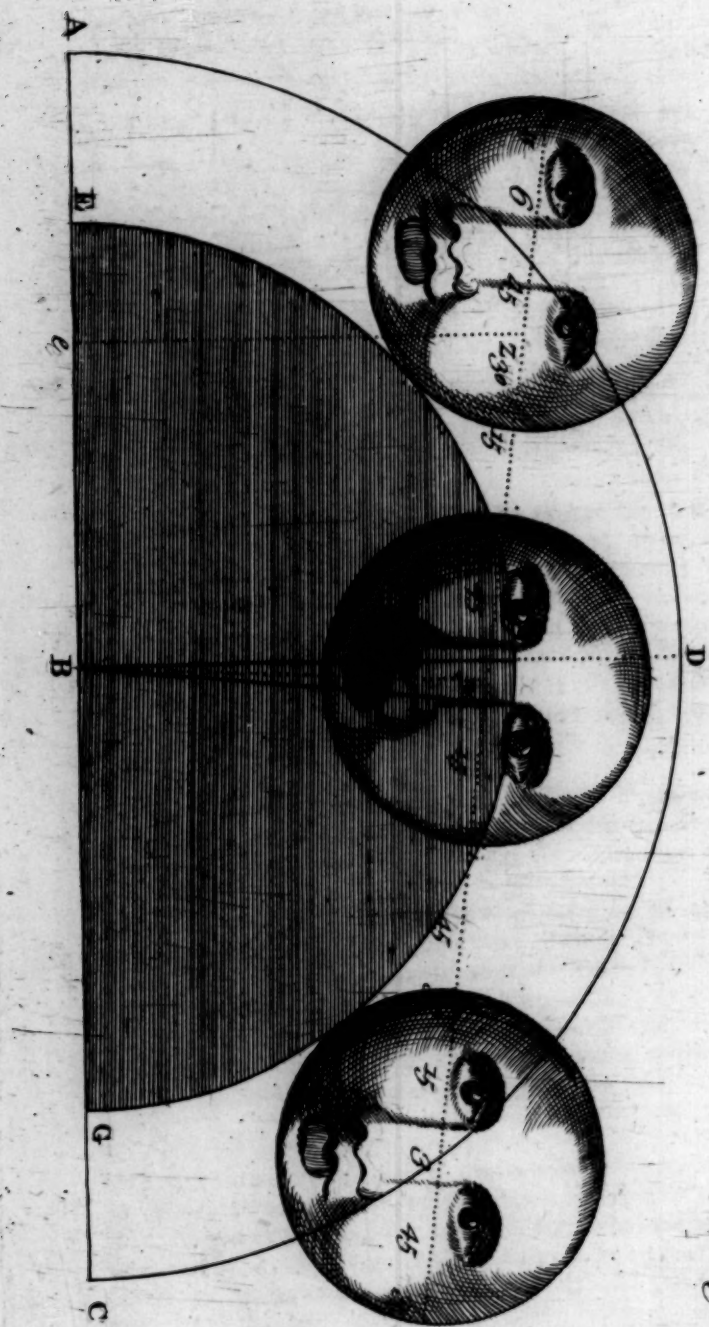
From whence the apparent time at Norwich,

	H.	M.	S.
Beginning January 23d, 1777, P. M.	3	4	11
Middle	4	27	33
Ecliptic 8	4	34	47
End	5	50	55
Duration	2	46	44
	0		
Digits eclipsed	6	57	31

Having thus shewn the method of calculating a lunar eclipse, I shall next shew how to solve the same by a geometrical construction.

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Plate 9.



The Geometrical Construction of the foregoing Lunar Eclipse.

1. Draw the right line, ABC , representing a part of the ecliptic, perpendicular to which draw BD , which will represent the northern part of its axis, the Moon in this eclipse having north latitude.

2. With the sum of the semi-diameters of the Moon and earth's shadow $56' : 12''$ from any scale of equal parts, with one foot of your compasses in B describe the semi-circle ADC ; in one point of which, towards the right hand, will the centre of the Moon be found, at the beginning of the eclipse; and at another point, towards the left hand, will her centre be found at the end thereof.

3. Take the semi-diameter of the shadow of the earth and atmosphere $40' : 52''$ in your compasses from the same scale, and setting in foot in B , describe the semi-circle EFG ; for the northern half of the earth's shadow, the Moon's latitude being north.

4. Make BF the radius of a line of chords on the sector, and set off the angle of the Moon's way with the ecliptic $5^{\circ} : 24'$ from F to H , and draw the right line BH , representing the northern half of the axis of the Moon's orb, lying to the right hand of the axis of the ecliptic BF , because the Moon's latitude is north ascending. Had the Moon's latitude been north descending, it would have fallen on the left thereof. The contrary is to be observed when the Moon's latitude is south ascending, or south descending.

5. Bisect the angle FBH , and draw the line Bx ; in this line the time of the true orbit δ of the Sun and Moon as shewn by the tables will be found.

6. Take the Moon's latitude at the time of the ecliptic δ $38' : 36''$ from the same scale, and set it from B to y , on the axis of the ecliptic; take her latitude at one hour after ecliptic δ and set it from e to z ; through y and z draw the right line m, o, n , for the path of the Moon's centre; then will m represent the place of the Moon's centre at the beginning of the eclipse o , her centre at the time of the greatest obscuration, and n the place of her centre at the end of the eclipse.

7. Take the hourly motion of the Moon from the Sun $29' : 31''$ in your compasses from the same scale; with that extent make marks along the line of the Moon's path, m, o, n , and divide them into 20 or 60 equal parts or minutes, setting the hours to the divisions in such sort that the dash signifying the minute of eclip-

tic 8, viz. 34 minutes 47 seconds past 4, in the afternoon, may be in the point y, where the path of the Moon cuts the axis of ecliptic.

8. Take the Moon's semi-diameter $15':20''$ in your compasses from the same scale, and with that extent as a radius upon the points r, o, s, as centres, describe circles representing the Moon at the beginning, middle, and end of the eclipse:

For the point r represents the instant of time when the eclipse begins, or when the first touches the earth's shadow, viz. 4 minutes 11 seconds after 3 o'clock, P.M. The point o, the middle, or instant of greatest obscuration, or 27 minutes 33 seconds after 4. And the points s shews the moment of the end of the eclipse, or instant the Moon's limb quits the earth's shadow, viz. 50 minutes 55 seconds after 5.

From hence it appears that the whole duration of the eclipse will be 2 hours, 46 minutes, 44 seconds, and digits obscured $60:57\frac{1}{2}$, exactly agreeing with the foregoing calculation.

A Calculation of the true Opposition of the Sun and Moon for a Lunar Eclipse on the 23d of November, 1779, Meridian of Greenwich.

	S.	°	'	"	S.	°	'	"
November 1700.	7	9	45	44	3	7	44	18
Complete } 76.			34	36			1	17
years } 3.	11	29	17	1			3	4
Days 23.		22	40	12				4
Hours 7.			17	15				
Minutes 39.			1	36		3	9	5
Seconds 48.				2				20
☉ mean motion	8	2	36	26				
Apogee —	3	9	5	20				
☉ mean anom.	4	23	31	6				
Cent. equ. —			1	10				4
☉ longitude	8	1	26	22				

Equation of apparent time + $13':11''$

☉ true latitude $3':16''$ S.D. ☉ horizontal parallax $59':15''$

☉ semi-diameter $16:9''$ ☉ semidiameter $16:18''$

☉ true hourly motion 35 30 ☉ hourly motion.

☉ ditto - - 2 32 In lat. $3':15''$.

Hourly motion ☉ a' ☉ 32 58

November

	S.	o	'	"	S.	o	'	"	S.	o	'	"
November 1700	2	26	39	9	11	0	15	43	5	1	13	16
Comp. } 76.		3	33	31	7	2	34	57				
Years } 3.		28	9	11	4	1	59	32		29	58	57
Days 23.	10	3	3	26		2	33	45		1	27	59
Hours 7.		3	50	35			1	57			1	13
Minutes 39.			21	24				11				56
Seconds 48.				27								5
Δ me. mo.	2	5	37	43	10	7	26	5				
1 equa.			+ 6	59			- 15	44	2	29	12	13
Δ 1 eq.	2	5	44	42	10	7	10	21	2	2	1	3
Apo. —	10	7	10	21						+ 5	40	
Δ me. anom.	3	28	34	21					2	2	6	43
6 lefs eq.			+ 9	38								
Δ an. 7 eq.	3	28	43	59	⊙ a' Δ apogee	9	24	16	1			
Cent. eq. —		5	42	39	2 ⊙ a' apogee	7	18	32	2			
Δ an. 8 eq.	3	23	1	20	⊙ a' Δ Ω	5	29	19	39			
Evect. +		1	14	32	2 ⊙ a' Δ Ω	11	28	39	18			
Δ an. 9 eq.	3	24	15	52	Mean evection	8	10	2	19			
Variation			— 1		Δ a' ⊙	5	29	59	51			
Δ an. 10 eq.	3	24	15	51	2 Δ a' ⊙	11	29	59	43			
Apo. +	10	7	10	21								
Δ in orb.	2	1	26	12								
Ω —		2	2	6								
Arg. lat.	11	29	19	29								
Reduc. +				10								
Δ long.	2	1	26	22								

The Calculation of a Lunar Eclipse that will happen on Tuesday,
November 23, 1779, P. M. in the Meridian of Norwich.

	H.	M.	S.
Ecliptic 8 mean time at Greenwich	7	39	48
Difference of meridians +		5	
Ecliptic 8 mean time at Norwich	7	44	48
Equation of apparent time +		13	11
Ecliptic 8 apparent time at Norwich	7	57	59
Double reduction in time +			36
Middle of the eclipse apparent time	7	58	35
Horizontal parallax of the ☽		59	15
Ditto of the Sun +			9
Sum		59	24
Semi-diameter of the Sun —		16	18
Semi-diameter of the earth's shadow		43	6
Atmosphere +			50
Semi-diameter, shadow, earth, and atmosphere		43	56
Semi-diameter of the ☽ +		16	9
Sum		60	5
			11
Semi-diameter of the earth's shadow and atmosphere		43	56
Semi-diameter of the ☽ —		16	9
Difference		27	47
Sum		60	5
Nearest approach of centres —		3	15
Parts deficient		0	56 50
			11
Digits eclipsed	21	6	21
Angle of the Moon's visible way	4	55	22
			"
Motion of semi-duration			3599
Motion of semi-duration in total darkness			1655
			"
	H.	M.	S.
Time of semi-duration	1	49	10
Time of semi-duration in total darkness		50	12
Middle of the eclipse apparent time	7	58	35
Semi-duration — and +	1	49	10
Beginning of the eclipse	6	9	25
End	9	47	45
Middle of the eclipse	7	58	35
Semi-duration of total darkness — and +		50	12
Beginning of total darkness	7	8	23
End of total darkness	8	48	47

Whence

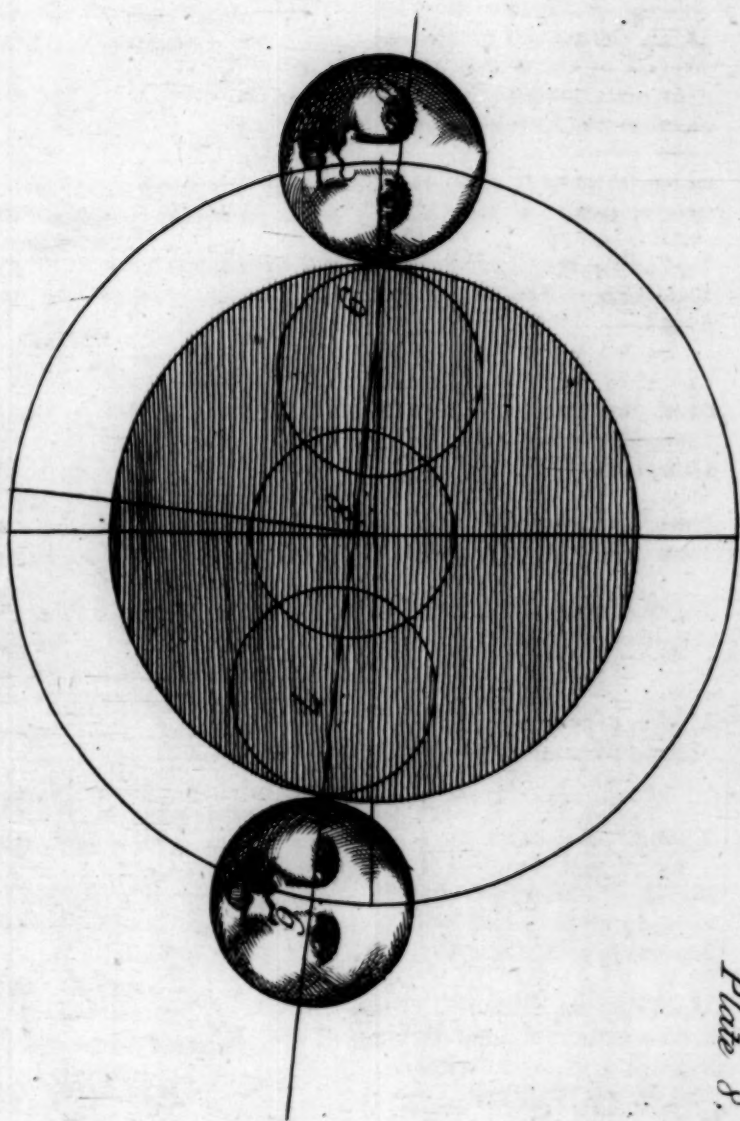


Plate 8.

4 00 58

Whence the apparent times at Norwich are,

	H.	M.	S.
Beginning at Norwich apparent time, Nov. 23d	6	9	25
Beginning of total darkness	7	8	23
Ecliptic 8	7	57	59
Middle	7	58	35
End of total darkness	8	48	47
End of the eclipse	9	47	45
Duration of total darkness	1	40	24
Duration of the eclipse	3	38	20
	0	1	11
Digits eclipsed	21	6	21

A Calculation of a mean Conjunction of the Sun and Moon for a Solar Eclipse, on Thursday, January 9, 1777, in the Meridian of Greenwich.

	S.	°	'	"		S.	°	'	"
January	1700	9	10	7 32		3	7	43	27
Comp. years	76			34 36		1	17	54	
	1	11	29	45 40				1	1
Days	9		8	52 15					
Hours	3			7 24					
Minutes	46			1 53		3	9	2	23
Seconds	56			2					

☉ me. mo. 9 19 29 23

Apo. — 3 9 2 23

☉ me. anom. 6 10 26 59

Cent. equ. + 21 27

☉ longitude 9 19 50 49

First equation of apparent time

Second equation of ditto

Absolute equation of apparent time

6 32 —

1 25 —

7 57 —

Sun's semi-diameter 16 21

Moon's semi-diameter 15 53

Moon's horizontal parallax 58 16

January

(40)

	S. ° / "	S. ° / "	S. ° / "
January 1700	1 11 1 42	9 26 23 38	5 17 19 10
Comp. Years } 76.	3 33 31	7 2 34 57	
Days	1. 4 9 23 3	1 10 39 50	29 58 57
Hours	9. 3 28 35 15	1 0 10	19 19 43
Minutes	3. 1 38 49	50	28 36
Seconds	46. 25 15	13	24
	56. 31		6
Δ me. mo.	9 24 38 6	6 10 39 38	
1 eq. —	— 2 7	+ 4 49	1 19 47 46
Δ 1 equat.	9 24 35 59	6 10 44 27	3 27 31 24
Apogee—	6 10 44 27		— 1 44
Δ me. anom.	3 13 51 32		3 27 29 40
6 less eq.	+ 5 56		
Δ anom. 7 eq.	3 13 57 28	⊙ a' Δ ap.	3 9 6 22
Cent. eq.	— 6 12 47	2 ⊙ a' Δ ap.	6 18 12 44
Δ anom. 8 eq.	3 7 44 41	⊙ a' Δ Ω	5 21 21 9
Evect.	+ 1 19 53	2 ⊙ a' Δ Ω	11 12 42 18
Δ anom. 9 eq.	3 9 4 34	Mean evect.	8 25 38 48
Variation	— 3	Δ a' ⊙	11 29 58 12
Δ anom. 10 eq.	3 9 4 31	2 Δ a' ⊙	11 29 56 24
Apo. +	6 10 44 27		
Δ in orb.	9 19 48 58		
Ω —	3 27 29 40		
Arg. lat.	5 22 19 18		
Reduc.	+ 1 51		
Δ long.	9 19 50 49		
Δ Lat.			

39 56 N.D.

A Cal-

A Calculation of a Solar Eclipse that will happen on Thursday,
January the 9th, 1777, P. M. for the Meridian of Norwich.

	H.	M.	S.
Ecliptic $\oslash$ mean time at Greenwich	-	3	46 56
Difference of meridians +	-		5
Ecliptic $\oslash$ mean time at Norwich	-	3	51 56
Equation of apparent—	-		7 57
Ecliptic $\oslash$ apparent time at Norwich	-	3	43 59
Longitude of the $\odot$ and $\oslash$ in the ecliptic	-	$\oslash$ 19	50 49
Sun's right ascension then	-	291	28 41
Apparent time from noon +	-	55	59 45
Right ascension of medium celi	-	347	28 26
Complement short of	-	$\oslash$ 12	31 34
Medium celi in the ecliptic	-	$\oslash$ 16	22 57
Meridian angle	-	67	6 58
Declination of the culminating point, S.—	-	5	22 52
Altitude of the equator at Norwich	-	37	15 0
Altitude of the medium celi	-	31	52 8
Altitude of the nonagesima degree	-	38	31 3
Distance of the medium celi from nonagesima	-	32	1 33
Nonagesima degree in	-	$\oslash$ 18	24 30
Moon from the nonagesima	-	88	33 41
Horizontal parallax of the $\oslash$ a' $\odot$	-		58 7
Parallax in longitude $\oslash$ a' $\odot$ —	-		36 16
Visible ecliptic longitude Moon	-	$\oslash$ 19	14 39
Moon's true latitude, N. D.	-		39 56
Parallax in longitude $\oslash$ a' $\odot$	-		45 32
Moon's visible latitude, S. D.	-		5 36

For the Place of the Medium Celi.

As radius	-	10.000000
To sc. 23:28:30 the obliquity	-	9.962481
So is tc. 12:31:34 right ascen. medium celi	-	10.653310
To tc. 13:37:3 distant from $\oslash$	-	10.615791
	S.	0 1 //
From $\oslash$	-	12 0 0 0
Take the distance from $\oslash$	-	13 37 3
Remain medium celi in the ecliptic	-	11 16 22 57

For the Meridian Angle.

As radius	0	'	"	-	-	10.0000000
To S. 23:28:30	-	-	-	-	-	9.600263
So is sc. 12:31:34	-	-	-	-	-	9.989537
To sc. 67:6:58 meridian angle	-	-	-	-	-	9.589800

For the Declination of the Culminating Point,

As radius	0	'	"	-	-	10.0000000
To t. 23:28:30	-	-	-	-	-	9.637783
So is f. 12:31:34	-	-	-	-	-	9.336228
To t. 5:22:52 south	-	-	-	-	-	8.974011

For the Altitude of the Medium Celi.

	0	'	"	-	-	-
Norwich elevation of the equator	-	-	-	-	-	37 15 0
Declination of the culminating point, S. —	-	-	-	-	-	5 22 52
Altitude of the medium celi	-	-	-	-	-	31 52 8

For the Altitude of the Nonagesima Degree.

As radius	0	'	"	-	-	10.0000000
To f. 67:6:58 meridian angle	-	-	-	-	-	9.964398
So is sc. 31:52:8 altitude medium celi	-	-	-	-	-	9.929040
To sc. 38:31:3 altitude nonagesima	-	-	-	-	-	9.893438

For the Place of the Nonagesima Degree.

As radius	0	'	"	-	-	10.0000000
To t. 58:7:52 co-altitude medium celi	-	-	-	-	-	10.206422
So is sc. 67:6:58	-	-	-	-	-	9.589799
To t. 32:1:33 dist. medium celi a' nonagesima	-	-	-	-	-	9.796221

Medium

	S.	0	'	"
Medium celi in	11	16	22	57
Distance medium celi from nonagesima +	1	2	1	33
Nonagesima degree in	0	18	24	30
Distance place subtract	9	19	50	49
Distance from the nonagesima	2	28	33	41

If the Place of the Medium Celi be in

{ V3, ♊, ♈, ♎, ♏, ♐, add. } The distance of the medium
 { ♑, ♒, ♓, ♍, ♌, ♋, subtr. } celi from the nonagesima to, or from the place of the medium
 celi; sum, or difference, is the place of the nonagesima.

For the Parallax in Longitude.

For the Parallax in Latitude.

As f. 58': 7" hor. par. 8.22799	As rad.	10.00000
To f. 38°: 31': 3" alt. no. 9.79432		
So is f. 88: 33: 41 Distance no. 9.99986	To f. 58': 7"	8.22799
	So is f. 38°: 31': 3"	9.89344
To f. 36': 10" par. long. 8.02217	To f. 45': 32" par. lat. 8.12143	

From the nonagesima subtract 3 signs, the descendent is in V3 18°: 24': 30", whence the luminaries are between the nonagesima and the descendent, or in the occidental quadrant; therefore the visible eclipse will happen after the true, so the requisites must be found to one hour after the ecliptic ♋, for finding the time of visible ♋.

Note, If the Moon's longitude be less than the longitude of the nonagesima, (as in this eclipse) she is then in the occidental quadrant; but if more, in the oriental.

For the Sun's right Ascension.

As radius	0	'	"	10.000000
To t. 70: 6: 40 Sun from ♎				10.441561
So is f. 23: 28: 30 the obliquity				9.962481
To t. 68: 28: 29 Sun's right ascension ♎				10.404042
	0	'	"	
Right ascension of ♎	360	0	0	
Right ascension found	68	28	29	
Sun's present right ascension	291	31	31	

G 2

At

	H.	M.	S.
At one hour after ecliptic δ	4	46	56
Diff. merid. +		5	
Mean time at Norwich	4	51	56
Equation of time —		7	57
Apparent time at Norwich	4	43	59
Moon in the ecliptic	V3	20	24
Sun's longitude then	V3	19	53
Sun's right ascension		291	31
Apparent time from noon		70	59
Right ascension of medium celi		362	31
Complement past	P	2	31
Medium celi in the ecliptic	P	2	44
Meridian angle		66	32
Declination of the culminating point, N. +		1	5
Altitude of the equator at Norwich		37	15
Altitude of the medium celi		38	20
Altitude of the nonagesima degree		43	59
Distance of the medium celi from the nonagesima		26	42
Nonagesima degree in	P	29	27
Moon from the nonagesima degree occidental		99	2
Horizontal parallax of the $\text{D a' } \odot$			58
Parallax in longitude $\text{D a' } \odot$ —			39
Visible ecliptic longitude D	V3	19	45
D true latitude	N. D.		36
Parallax in latitude $\text{D a' } \odot$			41
D visible latitude	S. D.		5
		0	' "
Visible place of the D at ecliptic δ	V3	19	14
Ditto one hour after ditto	V3	19	45
Visible hourly motion of the Moon			31
Hourly motion of the Sun			2
Visible hourly motion $\text{D a' } \odot$			28

As $28': 39'' = 1719''$ to 1 hour = $3600''$, so is $36': 10'' = 2170''$ the parallax in longitude $\text{D a' } \odot$ at ecliptic δ to $7812000'' = 1$ hour, 15 minutes, 44 seconds, the interval in time from true to visible δ . This interval in time if the luminaries are occidental, as in this eclipse, add; but oriental, subtract to, or from; the time of true δ gives the time of visible δ .

	H.	M.	S.
Apparent time of true δ at Norwich	3	43	59
Interval in time add	1	15	44
Apparent time of visible δ at Norwich	4	59	43
Diff. meridians subtract		5	
Apparent time of visible δ at Greenwich	4	54	43
Equation of time +		7	57
Mean time of visible δ at Greenwich	5	2	40

To this time compute the longitude of the $\odot$ and D .

Visible

	H.	M.	S.
Visible δ apparent time at Norwich	4	59	43
Moon's true longitude	V 20	33	56
Sun's longitude then	V 19	53	59
Sun's right ascension	291	32	15
Apparent time from noon	74	55	45
Right ascension of medium celi	366	28	0
Complement past	γ 6	28	0
Medium celi in the ecliptic	γ 7	2	39
Meridian angle	66	40	56
Declination of the culminating point, N. +	2	48	1
Altitude of the equator at Norwich	37	15	0
Altitude of the medium celi	40	3	1
Altitude of the nonagesima	45	39	2
Distance medium celi from the nonagesima	25	12	57
Nonagesima degree in	8	2	15
Moon from the nonagesima	101	41	40
Horizontal parallax Δ a' $\odot$		58	7
Parallax in longitude Δ a' $\odot$		40	42
Visible longitude Δ in the ecliptic	V 19	53	14
Moon's true latitude, N. D.		35	56
Parallax in latitude Δ a' $\odot$		40	38
Moon's visible latitude, S. D.		4	42

	H.	M.	S.
At one hour before-visible δ	3	59	43
Moon's longitude in the ecliptic	V 19	59	48
Sun's place then	V 19	51	28
Sun's right ascension	291	29	33
Apparent time from noon	59	55	45
Right ascension of medium celi	351	25	18
Complement short of γ	8	34	42
Medium celi in the ecliptic	γ 20	39	38
Meridian angle	66	48	12
Declination of the culminating point, S. —	3	42	24
Altitude of the equator at Norwich	37	15	—
Altitude of the medium celi	33	32	36
Altitude of the nonagesima	40	0	33
Distance of the medium celi from the nonagesima	30	42	54
Nonagesima degree in	γ 21	12	32
Moon from the nonagesima degree	91	12	44
Horizontal parallax of the Δ a' $\odot$		58	7
Parallax in longitude Δ a' $\odot$ —		37	21
Visible longitude Δ in the ecliptic	V 19	22	27
Ditto a visible δ	V 19	53	14
Visible hourly motion Δ		30	47
Hourly motion $\odot$ —		2	31
Visible hourly motion Δ a' $\odot$		28	16
Moon's true latitude, N. D.		39	6
Parallax in latitude		44	31
Moon's visible latitude, S. D.		5	25
			At

	H.	M.	S.
At one hour after visible δ	5	59	43
Moon's longitude in the ecliptic	VS 21	8	4
Sun's place then	VS 19	56	30
Sun's right ascension	291	34	54
Apparent from noon	89	55	45
Right ascension of medium celi	381	30	39
Complement past	γ 21	30	39
Medium celi in the ecliptic	γ 23	15	14
Meridian angle	68	14	53
Declination of the culminating north $\dagger$	9	2	53
Altitude of the equator at Norwich	37	15	—
Altitude of the medium celi	46	7	53
Altitude of the nonagesima	49	55	24
Distance of the medium celi from the nonagesima	19	36	27
Nonagesima degree in	8 12	51	41
Moon from the nonagesima	111	43	37
Horizontal parallax of the $\mathfrak{D}$ a' $\odot$		58	7
Parallax in longitude $\mathfrak{D}$ a' $\odot$ —		41	18
Visible longitude $\mathfrak{D}$ in the ecliptic	VS 20	26	46
Ditto at visible δ	VS 19	53	14
Visible hourly motion of the $\mathfrak{D}$		33	32
Visible hourly motion of the $\odot$		2	31
Visible hourly motion of the $\mathfrak{D}$ a' $\odot$		31	1
Moon's true latitude, N. D.		32	46
Parallax in latitude		37	25
Moon's visible latitude, S. D.		4	39

For the Angle of visible Way of the $\mathfrak{D}$ at visible δ .

Visible longitude $\mathfrak{D}$ a' $\odot$ 1 hour before visible δ	28	16
Ditto at 1 hour after 1 ditto	31	1
Longitude $\mathfrak{D}$ a' $\odot$ in 2 hours	59	17
Visible latitude $\mathfrak{D}$ a' $\odot$ 1 hour before visible δ	5	25
Ditto at 1 hour after ditto	4	39
Difference of visible latitudes in 2 hours	0	46

As s. $59^{\circ} 17''$ visible longitude $\mathfrak{D}$ a' $\odot$ in 2 hours 8.23662

To radius — — — 10.00000

So is t. $46''$ different visible lat. in 2 hours 6.34834

To t. $44^{\circ} 28''$ ang. visible way $\mathfrak{D}$ at visible δ 8.11172

For

For the Motion from visible δ to the greatest Obscuration,

As radius	-	-	10.00000
To f. $4':42''$ visible latitude $\mathcal{D}$ at visible δ	-	-	7.13361
So is f. $44':28''$ ang. visible way $\mathcal{D}$ at visible δ	-	-	8.11171
To f. $4''$ motion from visible δ to greatest obscuration	-	-	5.24532

For the visible dist. Centres $\odot$ and $\mathcal{D}$ at greatest Obscuration.

As radius	-	-	10.00000
To f. $4':42''$ visible latitude $\mathcal{D}$ at visible δ	-	-	7.13361
So is f. $44':28''$ ang. visible way $\mathcal{D}$ at visible δ	-	-	9.99996
To f. $4':41''$ visible dist. centres $\odot$ and $\mathcal{D}$ at great. obscur.	-	-	7.13357

As $59':17''=3557''$ visible hourly motion $\mathcal{D}$ a' $\odot$ in 2 hours is to 2 hours $=7200''$, so is $4''$ motion from visible δ to greatest obscuration to $8''$ interval in time from visible δ to greatest obscuration; which interval, because the $\mathcal{D}$ visible latitude is descending, add; but if ascending, subtract.

		H. M. S.
Visible δ	-	4 59 43
Interval +	-	8
Time of greatest obscuration	-	4 59 51

Semi-diameter Sun $16':21''$ + semi-diameter $\mathcal{D}$ $15':53''$ = semi-diameter penumbra $=32':14''$ in seconds is $1934''$, its square is 3740356 . Nearest visible distance of centres $\odot$ and $\mathcal{D}$ $4':41''$ in seconds is 281 , its square in seconds is 78961 ; then $3740356 - 78961 \sqrt{3661395}$, its square root in seconds, is $1913''=31':53''$ visible motion of semi-duration.

Semi-diameter of the penumbra $32':14''$ —visible distance centres $4':41''=27':33''=1653''$ parts deficient; then as semi-diameter of the $\odot$ $16':21''=981''$ to 6 digits, so is parts deficient $1653''$ to digits eclipsed $10^0:6':36''$.

		' "
$\mathcal{D}$ visible latitude at 1 hour before visible δ	-	5 25
Ditto at visible δ	-	4 42
Difference of visible latitudes	-	0 43

As f. 28': 16" visible motion $\mathcal{D}$ a' $\odot$ 1 hour before vis. δ 7.91454

To radius - - - 10.00000

So is t. 43" different visible latitudes - 6.31905

To t. 27': 9" visible way $\mathcal{D}$ with the ecliptic, from be- }
ginning eclipse to greatest obscuration - } 8.40411

As radius - - - 10.00000

To f. 31': 53" visible motion of semi-duration - 7.96726

So is t. 27': 9" visible motion above - 9.99999

To f. 31': 53" visible motion in longitude from the be- }
ginning eclipse to greatest obscuration - } 7.96725

As 28': 16" = 1696" visible hourly motion $\mathcal{D}$ a' $\odot$ at 1 hour be-
fore visible δ to 1 hour = 3600", so is 31': 53" = 1913" to 4060"
= 1 hour, 7 minutes, 40 seconds, the time of incidence.

As 31': 1" = 1861" visible hourly motion $\mathcal{D}$ a' $\odot$ 1 hour after
visible δ to 3600", so is 1913" to 3700" = 1 hour, 1 minute, 40
seconds, time of repletion,

	H.	M.	S.
Greatest obscuration	4	59	51
Time of incidence subtract	1	7	40
Beginning of the eclipse	3	52	11
Greatest obscuration	4	59	51
Time of repletion add	1	1	40
End of the eclipse	6	1	31

Time of incidence + time of repletion gives the
H. ' " H. ' " H. ' "

Duration of the eclipse, viz. 1:7:40 + 1:1:40 = 2:9:20.

	H.	M.	S.
Beginning of the eclipse at Norwich apparent time	3	52	11
Visible δ - - -	4	59	43
Greatest obscuration - - -	4	59	51
End of the eclipse - - -	6	1	31
Duration - - -	2	9	20
Digits eclipsed = - - -	10 ⁰	6	36

Calculation

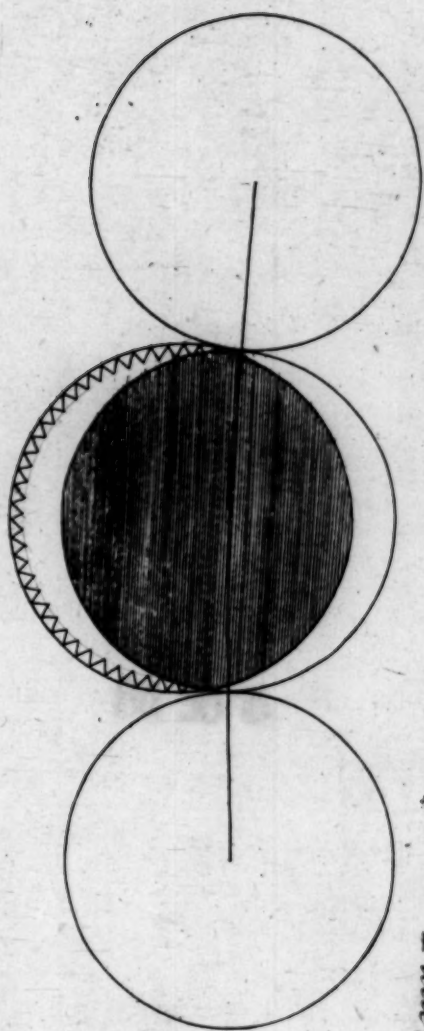
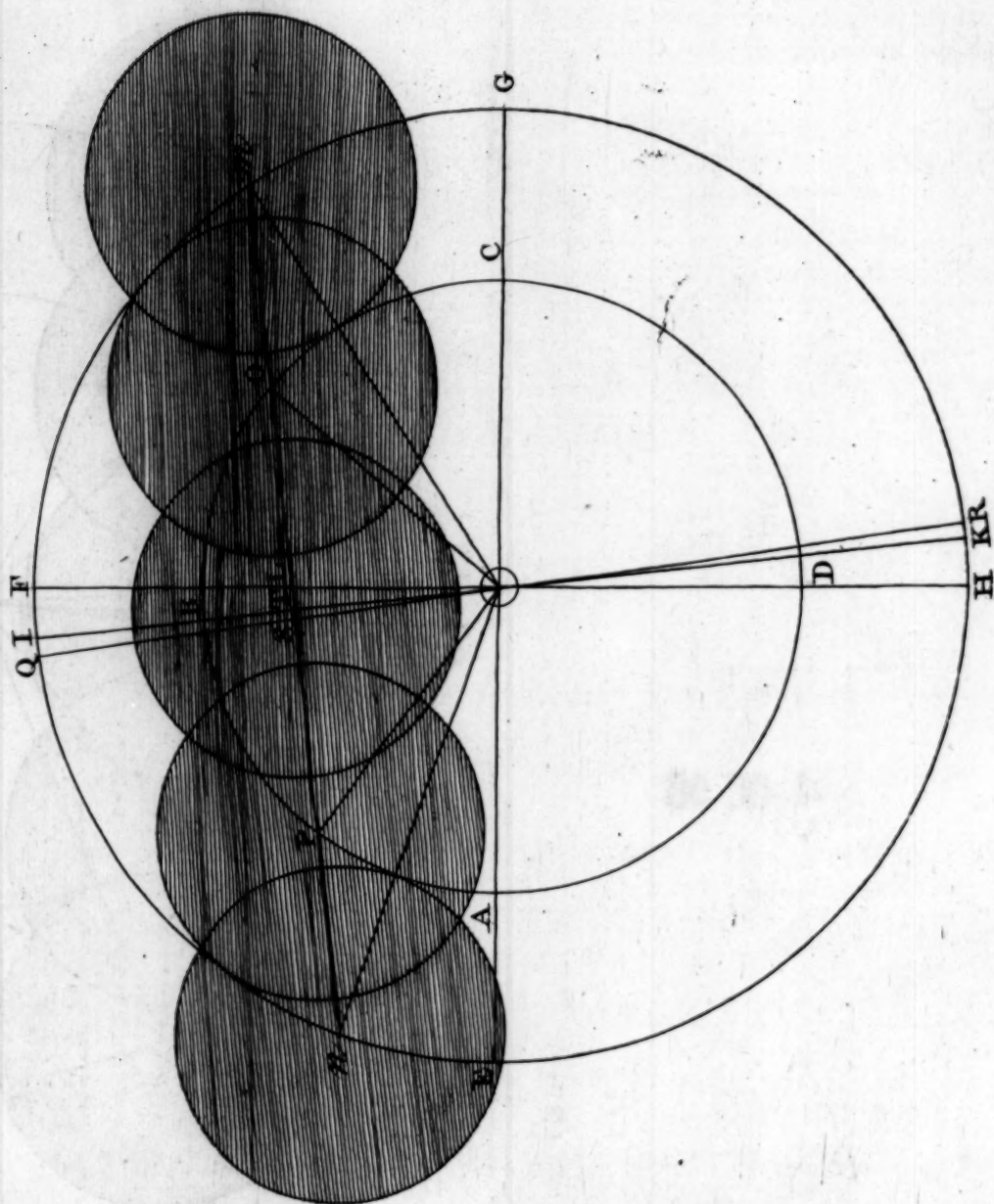


Plate 5.

Plate 6.



Calculation and Projection of the general Eclipse of the Sun,
January 9, 1777.

	'	"
Semi-diameter of the earth's disk	58	7
Semi-diameter of the penumbra	32	14
Semi of the disk and penumbra	90	21
Hourly motion of the ☽	34	8
Ditto of the Sun	2	31
Ditto of the ☽ a' ☉	31	37

Projection.—Take from a scale of equal parts the semi-diameter of the earth's disk $58':7''$, with one foot of the compasses in ☉ describe the circle ABCD, representing the horizon of the earth's disk; from the same scale take the semi-diameter of the disk and penumbra $90':21''$, at 1 foot in ☉ describe EFGH, and draw EG the ecliptic, and FH its axis; take $5^\circ:23'$ the angle of the ☽'s way from a line of chords, and set it from F to I, and draw IK the axis of the ☽'s orb, which will lie to the left hand of the axis of the ecliptic, because the ☽'s true latitude is N. D. but to the right hand in N, or S. A.

From the same scale of equal parts take the ☽'s latitude $39':56''$ and set it from ☉ to L, through L, and at right angles to IK, draw mn, the ☽'s orb, or line of her way over the disk, or path of the penumbra. From the same scale with the semi-diameter of the penumbra $32':14''$ with one foot in M O L P, and N, respectively, draw circles representing the centre of the penumbra at those places in its passage over the earth's disk; draw lines from ☉ to M O P, and N, forming the triangles ☉ M L, ☉ O L, ☉ L P, and ☉ L N.

Then in the triangle, ☉ L M, are given ☉ M, $90':21''$, the sum of the semi-diameters of the disk and penumbra, and ☉ L $39':56''$, the ☽'s latitude. To find the angle, M O L, the first angle of incidence, and M L, the motion of the penumbra from L to M, or half the motion of general eclipse.

Also in the triangle, ☉ L O, are given ☉ O, the semi-diameter of the disk, $58':7''$, and ☉ L the ☽'s latitude, $39':56''$. To find L ☉ O, the second angle of incidence, and O L, half the motion of the central eclipse.

Remark.—If the Sun be in ☊, ♏, ♍, ♋, ♌, or ♈, the axis of the globe lies to the right hand of the axis of the ecliptic; but if the Sun be in ♊, ♎, ♐, ♑, ♒, or ♓, the axis of the globe lies to the left hand of the axis of the ecliptic.

Take the chord $8^\circ:23'$, the inclination of the axis of the globe with the axis of the ecliptic, and set it from F to Q, and
H draw

draw QR , the axis of the globe projected in the earth's disk. Whence as the axis of the globe and the axis of the ecliptic lies on one and the same side of the axis of the ecliptic, the angle, $Q \odot F$, will be negative (otherwise affirmative). Whence from the angle, $Q \odot F$, $8^{\circ}:23'$, take the angle, $I \odot F$, $5^{\circ}:23'$, the difference, $3^{\circ}:00'$, will be the angle, $Q \odot I$ the angle of direction.

Lastly, in the triangle, $L \odot S$, are given the angle of direction, $L \odot S$, $3^{\circ}:00'$, and the D 's latitude $\odot L$ $39':56''$, to find LS .

Remark.—If the sum of the semi-diameters of the earth's disk and penumbra be greater than the D 's latitude at true $\odot$, shews the Sun will be eclipsed.

Also, if the D 's true latitude be less than the semi-diameter of earth's disk, shews the Sun will be centrally eclipsed to some part of the earth: but if the difference between the semi-diameter of the earth's disk and penumbra be less than the D 's true latitude, proves the penumbra will not all fall within the earth's disk, and that there will be but two angles of incidence.

C A L C U L A T I O N.

	H.	M.	S.
Apparent time $\odot$ Norwich, January 9, 1777	3	43	59
Sun and Moon in the ecliptic	$\vee$ 19	50	49
Moon's true latitude, N. D.		39	56
Hourly motion $D \text{ a' } \odot$		34	8
Semi-diameter of the $\odot$		16	21
Ditto of the Moon		15	53
Breadth of the annulus		—	28
Angle of the D way		5	23

For the Angle of the D 's visible Way.

S. $\odot$ ' "	
As f. $5:22:19:18$ argument latitude	9.12584
To radius	10.00000
So is f. $39':56''$ D latitude	8.06488
To f. $4^{\circ}:59'$ angle, A.	8.93904

(51)

As $31': 37'' = 1897''$ log. co. ar. ho. mo. $\Delta a' \odot$ 6.72193
 To $34: 8 = 2048''$ log. hourly mo. Δ - 3.31133
 So is f. $4^\circ: 59'$ ang. A. - 8.93904

To f. $5^\circ: 23'$ ang. vis. way Δ with the ecliptic 8.97230

As sum semi-diam. disk and penumbra $90': 21''$ 3.73408

To radius - 10.00000

So is Δ lat. $39': 56'' = 2396''$ - 3.37949

To fc. $63^\circ: 46'$ ang. incidence $M \odot L$ 9.64541

As radius - 10.00000

To $\odot M$. $90': 21'' = 5421''$ - 3.73408

So is f. $63^\circ: 46'$ $M \odot L$ - 9.95279

To LM $4862''$ motion of $\frac{1}{2}$ duration - 3.68687

As $948''$ half hourly motion $\Delta a' \odot$ to half an hour, or $1800''$,
 so is half the motion of duration, $2431''$, to the time of half du-
 ration $= 4615 \times 2 = 9230'' = 2$ hours, 33 minutes, 50 seconds, time
 the penumbra is moving from M to L .

As $\odot O$ $58': 7''$ semi-diam. disk $= 3487''$ - 3.54245

To radius - 10.00000

So is $\odot L$ $39': 56'' = 2396''$ Δ latitude - 3.37949

To fc. $L \odot O$ $46^\circ: 36'$ second ang. incidence - 9.83704

As radius - 10.00000

To $\odot O$ $3487''$ semi-diam. disk - 3.54245

So is f. $46^\circ: 36'$ - 9.86128

To OL $2533''$ half mo. central eclipse - 3.40373

As $1897''$ hourly motion $\Delta a' \odot$ to $3800''$, or 1 hour, so is
 $2533''$, half motion of central eclipse, to 4859 time of ditto.

H 2

As

As

As radius	10.00000
To sc. $70^{\circ} : 9' : 11''$ $\odot$ from γ	9.53086
So is t. $23 : 28' : 30''$ declination	9.63778
To t. $8^{\circ} : 23'$ declination of the z axis	9.16864

From the angle $Q \odot F$	8 23
Take the angle $I \odot F$	5 23
Remain the angle $Q \odot I$ of direction	3 00

As radius	10.00000
To $\odot L$ $39' : 56'' = 2396''$ Δ latitude	3.37949
So is t. $3^{\circ} : 00'$ angle $Q \odot I$ of direction	8.71940
To LS $126'$ motion thereof	2.09889

As $1897'' : 3600'' :: 126'' : 239'' = 3' : 59''$ time, which added to the apparent time of the middle of the eclipse gives the apparent time when the meridional Sun will be centrally eclipsed.

By collecting the results of these operations we have the angle of the Δ way

First angle of incidence $5^{\circ} 23' 63 46$

Motion of semi-duration 4862

Time of ditto $H. M. S. 2 33 50$

Second angle of incidence $46 36$

Motion of semi-duration of central eclipse 2533

Time of ditto $H. M. S. 1 20 59$

Angle of inclination of the z axis $8 23$

Angle of direction $3 0$

Motion

Motion from the axis to nearest approach 126

Time of ditto M. S.
3 59

	H.	M.	S.
Apparent time of ecliptic & Norwich, 1777, Jan. 9	3	43	59
Double reduction in time +		7	1
Apparent time of the middle eclipse	3	51	0
Semi-duration of general eclipse — and +	2	33	50
Beginning of general eclipse	1	17	10
End of ditto	6	24	50
Middle of the eclipse	3	51	0
Time from the axis to the nearest approach		3	59
Sun centrally eclipsed in the meridian	3	54	59
Middle of the eclipse	3	51	0
Semi-duration of central eclipse — and +	1	20	59
Beginning of central eclipse	2	30	1
End of ditto	5	11	59

For the Sun's Declination.

As radius	10.00000
To f. $70^{\circ}:9'$ ☉ from ♀	9.97339
So is f. $23^{\circ}:29'$ greatest declination	9.60047
To f. $22^{\circ}:1'$ present declination S.	9.57380

General

General Appearances of the Solar Eclipse, January 9, 1777,
apparent Time in the Meridian of Norwich.

	H.	M.	S.	Latitude.	Lon. a' Nor.
				° /	° /
Eclipse begins at ☉ rise	1	17	10	26 55 N.	96 30 W.
☉ rises centrally eclipsed	2	30	1	42 10	105 00
☉ cent. eclips. in the nonag.	3	43	59	20 53	50 00
☉ cent. eclips. mid. transit	3	51	0	22 55	51 30
☉ cent. eclips. in the merid.	3	54	59	21 2	58 45
☉ set centrally eclipsed	5	11	59	36 56	20 30
Eclipse end at ☉ set	6	24	50	21 27	16 2
☉ upper touched by the } ☾ lower limb -	3	54	59	14 24 S.	58 45
☉ lower touched by the } ☾ upper limb -	No where.				
Duration of the general } eclipse -	5	7	40		
Duration of the central } eclipse -	2	41	58		

To find the Place on the Earth where, in a Solar Eclipse, the Eclipse is seen to begin first at Sun-rise.

First angle of incidence	-	-	63	46
Angle of direction subtr.	-	-	3	00
Amplitude of the path	-	-	60	46
As radius	-	-	10.00000	
To sc. $22^{\circ}:1'$ $\odot$ declin. south	-	-	9.96712	
So is sc. $60:46$ the amp.	-	-	9.68875	
To f. $26^{\circ}:55'$ latitude of the place north	-	-	9.65587	

For the Ascensional Difference.

As radius	-	-	10.00000	
To t. $26^{\circ}:55'$ latitude north	-	-	9.70561	
So is t. $23:29$ declin. north	-	-	9.63795	
To f. $12^{\circ}:45'$ ascen. difference	-	-	9.34356	

For the Difference of Meridians.

	H.	M.
Ascension difference $12^{\circ}:45'$ in time is	0	51
Add	6	0
True time of Sun-rise	6	51
Time at Norwich then	1	17
Difference of meridians $96^{\circ}:30'$ West	6	26

For the Latitude and Longitude of the Place where the Sun rises centrally eclipsed.

Second angle of incidence	-	-	46	36
Angle of direction subtr.	-	-	3	00
Amplitude of the path	-	-	43	36

As

(56)

As radius		10.00000
To sc. $22^{\circ}:1'$ $\odot$ declin S.		9.96712
So is sc. $43:36$ amplitude path		9.85984
To f. $42^{\circ}:10'$ latitude of the place North		9.82696

	H. M.
Ascension difference $22^{\circ}:50'$ in time is	1 31
Add	6 00
True time of Sun-rise	7 31
Time at Norwich	2 31
Diff. of meridians $105^{\circ}:00'$ W.	7 00

To find the Place where the $\odot$ is centrally eclipsed in the Meridian.

As semi-diameter earth's disk $58':7''=3487''$ log.	3.54245
To radius	10.00000
So is dist. a' centre earth to $\odot$ path on univ. merid. $2380''$	3.37658
To S. $\odot$'s dist. in merid. a' vertex $43 \quad 3$	9.83413
Sun's declination subtr. $22 \quad 1$	
Latitude North $21 \quad 2$	

	H. M.
Time there is noon, or	24 0
Time at Norwich, +	3 55
Diff. of meridians $58^{\circ}:45'$ W.	3 55

To find the Place where the Sun is centrally eclipsed in the Nonagesima Degree.

As semi-diameter earth's disk log. $3487''$	3.54245
To radius	10.00000
So is $\odot$ dist. in the axis ecliptic $2390''$ log.	3.37839
To f. azimuth between $\odot$ and vertex $43^{\circ}:16'$	9.83594

As

As radius	10.00000
To sc. $8^{\circ}:23'$ inclination 2 axis	9.99534
So is t. $43:16$ $\odot$ a' the vertex	9.97371
To t. $43^{\circ}:0'$ A. 4th arc.	9.96905

Sun's declination S.	22	1
Add	90	0
Sun's dist. from N. pole, D latitude being N.	112	1
4th arc. subtr.	43	0
5th arc.	69	1

As sc. $43^{\circ}:00'$ the 4th arc. co. ar.	0.13587
To sc. $69:1$, the 5th arc.	9.55399
So is sc. $43:16$ $\odot$ a' vertex	9.86223
To f. $20^{\circ}:53'$ latitude North	9.55209

As f. 5th arc. $69^{\circ}:1'$ co. ar.	0.02979
To f. 4th. arc. $43:0$	9.83378
So is t. $8^{\circ}:23'$ inclin. 2 axis	9.16849
To t. $6^{\circ}:9'$ hour from noon $\odot$ in nonagesima	9.03206

H.	0	1
Time at Norwich 3 44 In degrees	48	45
Sun in the nonag. 0 24 In degrees	6	9
Long. W. - 3 20 In degrees	50	0

This same operation finds the latitude and longitude where the eclipse is central at the middle of the transit of the penumbra; only in second proportion, instead of sc. of the inclination take the sc. of the angle of direction, and in the first proportion take D's latitude instead of the Sun's distance in the axis of the ecliptic.

To find the Place where the $\odot$ sets centrally eclipsed.

Second angle of incidence	46	36
Angle of direction +	3	00
Path of the amplitude	49	36

As

As radius	10.00000
To sc. $22^{\circ}:1''$ $\odot$ declin. S.	9.96712
So is sc. $49:36$ path amplitude	9.81166
To f. $36^{\circ}:56'$ latitude North	9.77878

For the Longitude.

	H.	M.
Ascensional difference $32^{\circ}:32'$ time	2	10
Subt.	6	0
The Sun sets	3	50
Time at Norwich	5	12
Diff. of meridians $20^{\circ}:30'$ W.	1	22

To find the Place where the Eclipse ends at Sun-set.

First angle of incidence	-	-	63	46
Angle of direction +	-	-	3	—
Amplitude of the path	-	-	66	46
As radius	-	-	10.00000	
To sc. $22^{\circ}: 1'$ Sun's declin. S.			9.96712	
So is sc. 66: 46 amplitude path			9.59602	
To f. $21^{\circ}: 27'$ latitude North	-	-	9.56314	

For the Difference of Longitude.

	H.	M.	S.
Ascensional $9^{\circ}:50'$ in time is	0	39	20
Subt.	6	—	—
Sun sets	5	20	40
Time at Norwich	6	24	50
Difference of meridians, West, $16^{\circ}:2'$	1	4	10

To find the Place where the $\odot$'s upper is touched by the D 's lower Limb in the Meridian.

Semi-diameter of the penumbra	32	14
Dist. D in the earth's axis from the centre disk	39	56
Difference	7	42

As

As semi-diameter earth's disk log. 3487"	3.54245
To radius	10.00000
So is difference $7': 42'' = 462''$ log.	2.66464
To f. $7^{\circ} : 37'$ Sun from the vertex	9.12219
Subt. $22^{\circ} : 1'$ Sun's declin. S.	
Latitude $14 : 24$ South	

The longitude is the same as where the Sun is centrally eclipsed in the meridian.

Sun rises centrally eclipsed long.	105	0 W.
Sun sets centrally eclipsed long.	20	30 W.
Length of the central shade in degrees	84	30 W.

Then $84^{\circ} : 30' = 84^{\circ}.5 \times 69'.5$, the miles in one degree, gives 5872'.75 English miles, the course of the central shade, westward.

Hourly motion Moon a' Sun $31.616 \times 69.5 = 2197.312$ statute miles, the hourly velocity of the central shade over the earth; which is something more than 36 miles per minute, an amazing swiftness, even exceeding that of the wind in a strong gale.

Geometrical Construction of the Solar Eclipse, January the 9th, 1777.

WITH the semi-diameter of the earth's disk, $58':7''$, from the line of lines on the sector, describe the semi-circle ABC , representing one half of the earth's illuminated disk projected on the plane of the ecliptic, $A \odot C$, set the chord of $23^\circ:29'$, the greatest declination from B to d and e , in which the pole of the world will be always found, set off the chord of $8^\circ:23'$ from B towards d , and draw $P \odot$, the axis of the world, which will always lie to the right hand of the axis of the ecliptic when the Sun is in $\varpi, \Omega, \mathbb{M}, \triangle, \mathbb{M},$ or $\uparrow$; but to the left hand if the Sun be in $\mathbb{V}, \mathbb{W}, \times, \Upsilon, 8, \text{II}.$

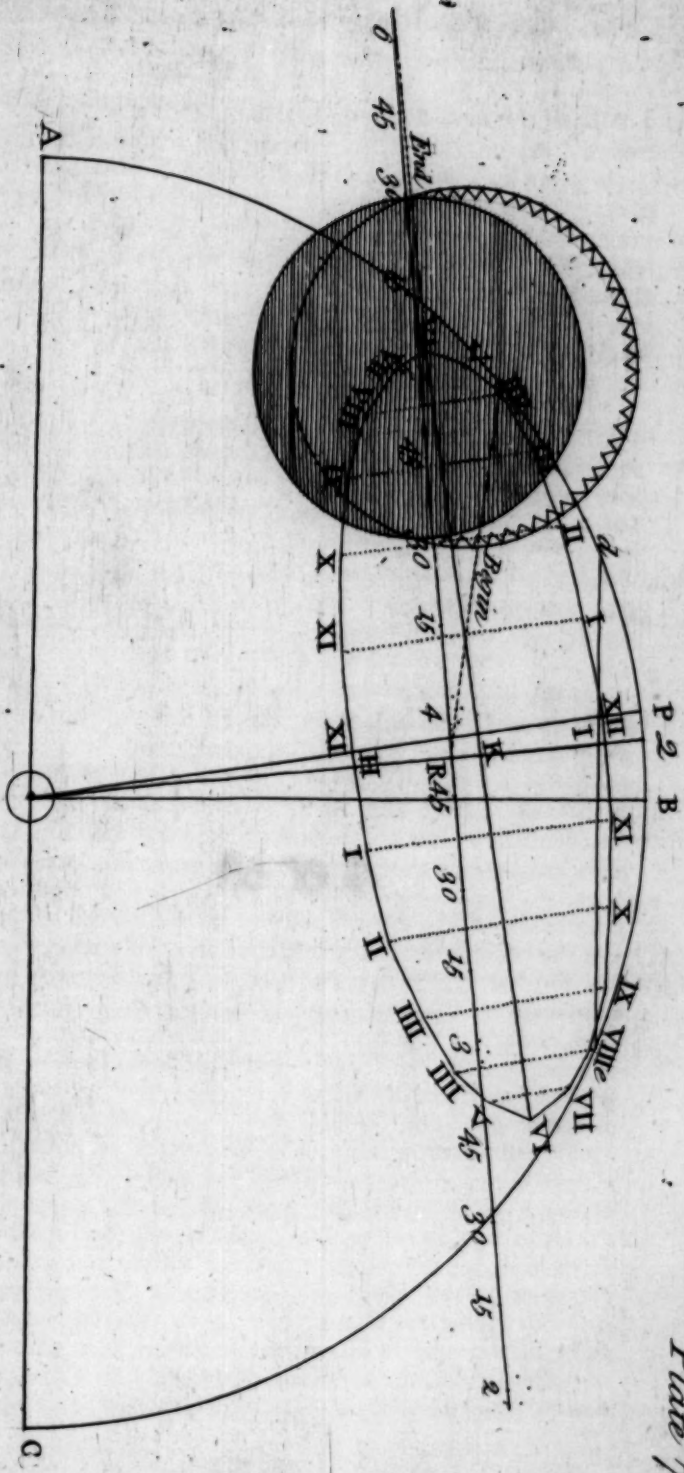
Latitude of Norwich	-	-	52	45	N.
Sun's declination add and subtr.	-	-	21	1	S.
Sun from the vertex at noon	-	-	73	46	
Sun from the vertex at midnight	-	-	31	44	

If the Sun's declination had been North in North latitudes, the sum will give the Sun's distance from the vertex at midnight, and the difference his distance from the vertex at noon.

Set the sine of $73^\circ:46'$ from $\odot$ to I , and the sine of $31^\circ:44'$ from $\odot$ to H , so will I be the meridional intersection of the diurnal arch of the path with the axis, and H the intersection of the nocturnal arch of the path of the vertex of Norwich with the meridian. Bisect HI , in K , at right angles to $P \odot$, and draw an occult line; take the sine of $37^\circ:15'$ the co. latitude, and with one foot of the compasses in K turn the other each way to 6 and 6, and draw the line 6, 6, which will represent the transverse axis of the earth's ellipsis to the vertex of Norwich, and HI the conjugate. Make $6K$ the radius of a line of sines, and take the sines of 15, 30, 45, 60, and 75° , and set them from K in the transverse each way to 6 and 6, through these points draw occult lines parallel to $P \odot$; make HK radius, and take the sines of 75, 60, 45, 30, and 15° , and with one foot in the transverse severally on each side K , at 15, 30, 45, &c. let the other foot fall in the occult lines, so will you have points through which the curve, representing the path of the vertex of Norwich, will pass; which curve will be an ellipsis, and when the Sun has South declination, will be on the upper side of the axis, $6K6$; but on the lower side when the Sun hath North declination. Also observe to divide the horary spaces in halves and quarters. Set the chord of $22^\circ:1'$ the Sun's declination South from A to L , and draw $\odot L$; set the chord $37^\circ:15'$ co. latitude from A to M , and draw MN perpendicular to the ecliptic AC , cutting $\odot L$ in O ; transfer $\odot O$ in the axis from $\odot$ towards K , through which point draw a line parallel to 6, 6, representing the amplitude of the path

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path of the vertex at Norwich, shewing $\odot$ rises after and sets before 6. Set off the chord of $5^{\circ}:23'$, from B to Q, to the left hand, because the Moon's latitude is N. D. but to the right hand when N. A. and draw $\odot Q$, the axis of the Moon's orb; take the sine $\mathcal{D}$ true latitude $39^{\circ}:56''$ to the radius of the disk, and set it from $\odot$ to R in the axis of the $\mathcal{D}$'s orb, through R, at right angles to $Q\odot$; draw TV, the path of $\mathcal{D}$ over the earth's disk during the time of eclipse,

H. M. S.

Apparent time of eclipsic δ at Norwich = 3 43 59

As 1 hour = 3600" is to the hourly motion of the $\mathcal{D}$ $a' \odot 31':37'' = 1897''$, so is the time past 10, viz. $43':59'' = 2639''$ to the motion of the $\mathcal{D}$ $a' \odot$ in that time $1390'' = 23':10''$.

Take $23':10''$ in your compasses to the radius of the disk, and set it from the axis of the ecliptic towards the right hand on the Moon's path, and it will mark out the hour of 3. From the same scale take $31':37''$, and set both ways from 3 to 2, and 4 from 4 to 5, and 6, the places where the centre of the penumbra will be at those hours; divide each hour into minutes. With the Sun's semi-diameter, $16':21''$, and one foot in the path of the vertex at the moment of visible δ , describe a circle representing the disk of the Sun at that time and place. With $15':53''$, the Moon's semi-diameter in the moment of visible δ , with 1 foot in the path of the Moon's way, describe a circle representing the Moon's disk at that time and place. With the sum of the semi-diameters of the $\odot$ and $\mathcal{D}$, and 1 foot in the path of the $\mathcal{D}$'s way, carry the other along the path of the vertex until both points fall in the same hour and minute, which will shew the beginning of the eclipse.

Carry the same extent towards the left hand, one foot in the path of the $\mathcal{D}$'s way, the other in the path of the vertex, till each foot fall in the same hour and minute, shewing the end of the eclipse.

Lastly.—Lay a ruler on the path of the $\mathcal{D}$'s way, moving it at right angles therewith from the right hand to the left, until the edge thereof cut the same hour and minute in the path of the $\mathcal{D}$'s way that it doth in the path of the vertex, then will that hour and minute be the time of visible δ .

Table of Mean Motions of
the Moon from the Sun
for 99 Julian Years.

	S.	0	'	"
4	5	20	41	0
8	11	11	21	59
12	5	2	2	59
16	10	22	43	59
20	4	13	24	59
24	10	4	5	58
28	3	24	46	58
32	9	15	27	58
36	3	6	8	57
40	8	26	49	57
44	2	17	30	57
48	8	8	11	57
52	1	28	52	56
56	7	19	33	56
60	1	10	14	56
64	7	0	55	56
68	0	21	36	55
72	6	12	17	55
76	0	2	58	55
80	5	23	39	54
84	11	14	20	54
88	5	5	1	54
92	10	25	42	54
96	4	16	23	53
1	4	9	37	23
2	8	19	14	47
3	0	28	52	10

Table of Mean Motion D a' ©
for Days.

	S.	0	'	"
1	0	12	14	27
2	0	24	22	53
3	1	6	34	20
4	1	18	45	47
5	2	0	57	13
6	2	13	8	40
7	2	25	20	7
8	3	7	31	33
9	3	19	43	0
10	4	1	54	27
11	4	14	5	53
12	4	26	17	20
13	5	8	28	47
14	5	20	40	13
15	6	2	51	40
16	6	15	3	7
17	6	27	14	33
18	7	9	26	0
19	7	21	37	27
20	8	3	48	53
21	8	16	0	20
22	8	28	11	47
23	9	10	23	13
24	9	22	34	40
25	10	4	46	7
26	10	16	57	33
27	10	29	9	0
28	11	11	20	27
29	11	23	31	53
30	0	5	43	20
31	0	17	54	47

In Leap Year take out a Day
sooner for Jan. and Feb.

A Table of the Mean Motions of the Moon from the
Sun for Hours, Minutes, and Seconds.

Ho.	o	'	"		o	'	"
1	0	30	29	31	15	44	47
2	1	0	57	32	16	15	16
3	1	31	26	33	16	45	44
4	2	1	54	34	17	16	13
5	2	32	23	35	17	46	42
6	3	2	54	36	18	17	10
7	3	33	20	37	18	47	39
8	4	3	49	38	19	18	7
9	4	34	18	39	19	48	36
10	5	4	46	40	20	19	5
11	5	35	15	41	20	49	33
12	6	5	43	42	21	20	2
13	6	36	12	43	21	50	31
14	7	6	41	44	22	20	59
15	7	37	9	45	22	51	28
16	8	7	38	46	23	21	56
17	8	38	6	47	23	52	25
18	9	8	35	48	24	22	54
19	9	39	4	49	24	53	22
20	10	9	32	50	25	23	51
21	10	40	1	51	25	54	19
22	11	10	30	52	26	24	48
23	11	40	58	53	26	55	17
24	12	11	27	54	27	25	45
25	12	41	55	55	27	56	13
26	13	12	24	56	28	26	43
27	13	42	53	57	28	54	11
28	14	13	21	58	29	27	40
29	14	43	50	59	29	58	8
30	15	14	19	60	30	28	37

Table of the Radical Mean Places and Motions of the Sun
and First Star of the Aries for Years and Months, Old Stile,
Greenwich, Latitude $51^{\circ}:28':30''$, North Longitude
 $00^{\circ}:00'$.

1600.	Julian, or Old Stile.												
Months.	Me. place Sun.					Mean Place Sun's Ap.				Me. Pla. α * φ			
	S.	o	'	''		S.	o	'	''	S.	o	'	''
January	1	9	20	12	31	3	6	00	59	0	27	35	10
February	1	10	20	45	49	3	6	1	40	0	27	35	14
March	0	11	18	21	42	3	6	1	90	0	27	35	18
April	0	0	18	55	01	3	6	1	140	0	27	35	22
May	0	1	18	29	11	3	6	1	190	0	27	33	27
June	0	2	19	2	29	3	6	1	240	0	27	35	31
July	0	3	18	36	39	3	6	1	290	0	27	35	35
August	0	4	19	9	57	3	6	1	350	0	27	35	39
September	0	5	29	43	15	3	6	1	400	0	27	35	44
October	0	6	19	17	25	3	6	1	450	0	27	35	48
November	0	7	19	50	43	3	6	1	500	0	27	35	52
December	0	8	19	24	53	3	6	1	550	0	27	35	56

1700.	Julian, or					Old Stile.							
	S. o ' "					S. o ' "				S. o ' "			
Months.													
January	1	9	20	58	33	7	43	29	0	28	59	20	
February	1	10	21	31	21	3	7	43	31	0	28	59	24
March	0	11	19	7	14	3	7	43	39	0	28	59	28
April	0	0	19	40	33	3	7	43	44	0	28	59	32
May	0	1	19	14	43	3	7	43	49	0	28	59	37
June	0	2	19	48	13	3	7	43	51	0	28	59	41
July	0	3	19	22	11	3	7	43	59	0	28	59	45
August	0	4	19	55	29	3	7	44	5	0	28	59	49
September	0	5	20	28	47	3	7	44	10	0	28	59	54
October	0	6	20	2	57	3	7	44	15	0	28	59	58
November	0	7	20	36	15	3	7	44	20	0	29	0	2
December	0	8	20	10	25	3	7	44	25	0	29	0	6

For the Radical Mean Place of the Sun's Apogee, &c. for any Month in the first Year of Christ, New or Old Stile, add the Mean Place for 1700, against the given Month, to 300 and 1 Years; from the Sum subtract the Radical Place for 2000 Years compleat, leaves the Radical Mean Place for the given Month first Year of Christ.

Table of the Radical Mean Places and Motions of the
Sun and First Star of Aries for Years and Months,
New Stile.

1600.	Gregorian, or New Stile.												
	Me. Place Sun.					Me. Pl. Sun's ap.				Me. Pl. 1 * ♀.			
Months.	S.	o	'	"		S.	o	'	"	S.	o	'	"
January	1	9	10	21	8	3	6	0	57	0	27	35	9
February	1	10	10	54	26	3	6	1	20	0	27	35	13
March	0	11	8	30	19	3	6	1	7	0	27	35	17
April	0	0	9	3	38	3	6	1	12	0	27	35	21
May	0	1	8	37	47	3	6	1	17	0	27	35	26
June	0	2	9	11	6	3	6	1	22	0	27	35	30
July	0	3	8	45	16	3	6	1	27	0	27	35	34
August	0	4	9	18	34	3	6	1	33	0	27	35	38
September	0	5	9	51	52	3	6	1	38	0	27	35	43
October	0	6	9	26	2	3	6	1	43	0	27	35	47
November	0	7	9	59	20	3	6	1	48	0	27	35	51
December	0	8	9	33	30	3	6	1	53	0	27	35	55

1700.	Gregorian, or New Stile.											
	<i>Jan 1st</i>				<i>Jan 1st</i>				<i>Apr 1st</i>			
	S.	o	'	"	S.	o	'	"	S.	o	'	"
January	o	9	10	7 32	3	7	43	27	o	28	59	19
February	o	10	10	40 50	3	7	43	32	o	28	59	23
March	o	11	8	16 43	3	7	43	37	o	28	59	27
April	o	o	8	50 2	3	7	43	42	o	28	59	31
May	o	1	8	24 12	3	7	43	47	o	28	59	36
June	o	2	8	57 30	3	7	43	52	o	28	59	40
July	o	3	8	31 40	3	7	43	57	o	28	59	44
August	o	4	9	4 58	3	7	44	3	o	28	59	48
September	o	5	9	38 16	3	7	44	8	o	28	59	53
October	o	6	9	12 26	3	7	44	13	o	28	59	57
November	o	7	9	45 44	3	7	44	18	o	29	o	1
December	o	8	9	19 54	3	7	44	23	o	29	o	5

Years Julian.	Mean Mot. Sun.				Mean Mot. Apo.				Mean Mot. ι * Υ .			
	S.	o	'	"	S.	o	'	"	S.	o	'	"
100	0	0	45	32	0	1	42	30	0	1	24	10
200	0	1	31	4	0	3	25	0	0	2	28	20
300	0	2	16	36	0	5	7	30	0	4	12	30
400	0	3	2	8	0	6	50	0	0	5	36	40
500	0	3	47	40	0	8	32	30	0	7	0	50
600	0	4	33	12	0	10	15	0	0	8	25	0
700	0	5	18	44	0	11	57	30	0	9	49	10
800	0	6	4	16	0	13	40	0	0	11	13	20
900	0	6	49	48	0	15	22	30	0	12	37	30
1000	0	7	35	20	0	17	5	0	0	14	1	40
2000	0	15	10	40	1	4	10	0	0	28	3	20
3000	0	22	46	0	1	21	15	0	1	12	5	0
4000	1	0	21	20	2	8	20	0	1	26	6	40
Yrs Greg. a' 1600.	Me. Mot. Sun.				Me. Mot. Apo.				Me. Mot. ι * Υ .			
	S.	o	'	"	S.	o	'	"	S.	o	'	"
100	11	29	46	24	0	1	42	30	0	1	24	10
200	11	29	32	47	0	3	25	0	0	2	48	20
300	11	29	19	11	0	5	7	30	0	4	12	30
400	0	0	4	43	0	6	50	0	0	5	36	40
500	11	29	51	7	0	8	32	30	0	7	0	50
600	11	29	37	30	0	10	15	0	0	8	25	0
700	11	29	23	54	0	11	57	30	0	9	49	10
800	0	0	9	26	0	13	39	59	0	11	13	19
900	11	29	55	50	0	15	22	29	0	12	37	29
1000	11	29	42	13	0	17	4	59	0	14	1	39

Mean Motion of the Sun and $\iota * \varphi$ for 99 Julian Years.

Julian Years.	Mean Mot. Sun.				Me. Mot. Apog.				Me. Mot. $\iota * \varphi$.			
	S.	o	'	"	S.	o	'	"				
4	—	—	1	49	—	—	4	6	—	—	3	22
8		+	3	39		+	8	12		+	6	44
12			5	28			12	18			10	6
16			7	17			16	24			13	28
20			9	6			20	30			16	50
24			10	56			24	36			20	12
28			12	45			28	42			23	34
32			14	34			32	48			26	56
36			16	24			36	54			30	18
40			18	13			41	0			33	40
44			20	2			45	6			37	2
48			21	51			49	12			40	24
52			23	41			53	18			43	46
56			25	30			57	24			47	8
60			27	19		1	1	30			50	30
64			29	8		1	5	36			53	52
68			30	58		1	9	42			57	14
72			32	47		1	13	48		1	0	36
76			34	36		1	17	54		1	3	58
80			36	26		1	22	0		1	7	20
84			38	15		1	26	6		1	10	42
88			40	4		1	30	12		1	14	4
92			41	53		1	34	18		1	17	26
96			43	43		1	38	24		1	20	48
1	11	29	45	40		1	1					50
2	11	29	31	20		2	3			1		41
3	11	29	17	1		3	4			2		31

Mean Mot. of the Sun and fixed Stars for Days, Hours, Minutes, &c.

Days.	Me. Mot. Sun.				Me. Mo. Stars	Ho. Min. Sec.	Me. Mo. Sun.			Ho. Min. Sec.	Me. Mo. Stars			
	S.	o	'	"			o	'	"		o	'	"	
1	—	—	59	8	0	0	1	—	2	28	31	1	16	23
2		1	58	17	0	0	2		4	56	32	1	18	5
3		2	57	25	0	0	3		7	24	33	1	21	19
4		3	56	33	1	0	4		9	51	34	1	23	47
5		4	55	42	1	1	5		12	19	35	1	26	14
6		5	54	50	1	1	6		14	47	36	1	28	42
7		6	53	58	1	1	7		17	15	37	1	31	10
8		7	53	7	1	1	8		19	43	38	1	33	38
9		8	52	15	1	1	9		22	11	39	1	36	6
10		9	51	23	2	1	10		24	38	40	1	38	34
11		10	50	32	2	1	11		27	6	41	1	41	1
12		11	49	40	2	2	12		29	34	42	1	43	29
13		12	48	48	2	2	13		32	2	43	1	45	57
14		13	47	57	2	2	14		34	30	44	1	48	25
15		14	47	5	2	2	15		36	58	45	1	50	53
16		15	46	13	3	2	16		39	20	46	1	53	21
17		16	45	22	3	2	17		41	53	47	1	55	48
18		17	44	30	3	2	18		44	21	48	1	58	16
19		18	43	38	3	3	19		46	49	49	2	0	44
20		19	42	47	3	3	20		49	17	50	2	3	12
21		20	41	55	3	3	21		51	45	51	2	5	40
22		21	41	3	4	3	22		54	13	52	2	8	8
23		22	40	12	4	3	23		56	40	53	2	10	36
24		23	39	20	4	3	24		59	8	54	2	13	3
25		24	38	28	4	3	25	1	1	36	55	2	15	31
26		25	37	37	4	4	26	1	4	4	56	2	17	59
27		26	36	45	4	4	27	1	6	32	57	2	20	27
28		27	35	53	5	4	28	1	9	0	58	2	22	55
29		28	35	2	5	4	29	1	11	27	59	2	25	23
30		29	34	10	5	4	30	1	13	55	60	2	27	50
31	1	0	33	18	5	4								
In leap year take out a day sooner for Jan. and Feb. both sides.														

In leap year take out a day sooner for Jan. and Feb. both fides.

Equation of the Sun's Centre.							
Argument of the Sun's Mean Anomaly.							
☉ M	Signs 0 Subt.	Signs 1 Subt.	Signs 2 Subt.	Signs 3 Subt.	Signs 4 Subt.	Signs 5 Subt.	☉ M
A	° / ' "	° / ' "	° / ' "	° / ' "	° / ' "	° / ' "	A
0	0 0 0	0 56 52	1 39 15	1 55 49	1 41 22	0 59 0	30
1	0 1 59	0 58 36	1 40 16	1 55 50	1 40 22	0 57 12	29
2	0 3 58	1 0 18	1 41 15	1 55 49	1 39 20	0 55 23	28
3	0 5 57	1 1 59	1 42 13	1 55 46	1 38 16	0 53 34	27
4	0 7 56	1 3 39	1 43 8	1 55 42	1 37 16	0 51 44	26
5	0 9 54	1 5 18	1 44 2	1 55 35	1 36 3	0 49 53	25
6	0 11 52	1 6 57	1 44 54	1 55 26	1 34 53	0 48 1	24
7	0 13 50	1 8 33	1 45 44	1 55 15	1 33 41	0 46 8	23
8	0 15 48	1 10 9	1 46 33	1 55 1	1 32 28	0 44 15	22
9	0 17 45	1 11 43	1 47 19	1 54 45	1 31 13	0 42 19	21
10	0 19 42	1 13 16	1 48 3	1 54 29	1 29 57	0 40 23	20
11	0 21 39	1 14 48	1 48 45	1 54 9	1 28 38	0 38 27	19
12	0 23 36	1 16 19	1 49 25	1 53 47	1 27 19	0 36 31	18
13	0 25 32	1 17 47	1 50 4	1 53 23	1 25 57	0 34 33	17
14	0 27 28	1 19 16	1 50 41	1 52 57	1 24 34	0 32 34	16
15	0 29 23	1 20 42	1 51 15	1 52 29	1 23 9	0 30 35	15
16	0 31 17	1 22 7	1 51 48	1 51 58	1 21 42	0 28 36	14
17	0 33 11	1 23 30	1 52 19	1 51 26	1 20 14	0 26 36	13
18	0 35 5	1 24 52	1 52 47	1 50 52	1 18 45	0 24 35	12
19	0 36 58	1 26 13	1 53 14	1 50 16	1 17 13	0 22 34	11
20	0 38 51	1 27 33	1 53 38	1 49 38	1 15 41	0 20 32	10
21	0 40 43	1 28 50	1 54 1	1 48 56	1 14 7	0 18 29	9
22	0 42 34	1 30 6	1 54 21	1 48 13	1 12 31	0 16 26	8
23	0 44 24	1 31 20	1 54 39	1 47 29	1 10 55	0 14 23	7
24	0 46 13	1 32 33	1 54 55	1 46 43	1 9 16	0 12 20	6
25	0 48 2	1 33 44	1 55 9	1 45 55	1 7 37	0 10 17	5
26	0 49 50	1 34 54	1 55 21	1 45 4	1 5 56	0 8 14	4
27	0 51 37	1 36 2	1 55 31	1 44 11	1 4 14	0 6 11	3
28	0 53 23	1 37 8	1 55 39	1 43 16	1 2 31	0 4 8	2
29	0 55 8	1 38 13	1 55 45	1 42 20	1 0 46	0 2 4	1
30	0 56 52	1 39 15	1 55 49	1 41 22	0 59 0	0 0 0	0
☉ M	Add Signs 11.	Add Signs 10.	Add Signs 9	Add Signs 8.	Add Signs 7	Add Signs 6.	☉ M
A							A

True hourly Motions and Semi-diameter Sun.										Table of the Sun's Par. and Refraction.									
Argument $\odot$ Me. Ano.										Argument of Sun's Altitude.									
S.	0'	"	'	"	0	S.	Al	'	"	Al	'	"	Al	"	Al	"	$\odot$'s Par. in Alt.		
0	0	2	23	15	49	0	12	0	33	45	21	2	18	56	36	0	//		
	5	2	23	15	49	25		$\frac{1}{4}$	30	24	22	2	11	57	35	0	10		
	10	2	23	15	49	20		$\frac{1}{2}$	27	35	23	2	5	58	34	3	10		
	15	2	23	15	49	15		$\frac{3}{4}$	25	11	24	1	59	59	32	6	10		
	20	2	23	15	50	10										9	10		
	25	2	23	15	50	5		1	23	7	25	1	54	60	31	12	10		
								$1\frac{1}{4}$	21	20	26	1	49	61	30				
1	0	2	24	15	51	0	11	$1\frac{1}{2}$	19	46	27	1	44	62	28	15	10		
	5	2	24	15	51	25		$1\frac{3}{4}$	18	22	28	1	40	63	27	21	10		
	10	2	24	15	52	20		2	17	8	29	1	36			24	10		
	15	2	24	15	53	15										27	10		
	20	2	25	15	54	10		$2\frac{1}{2}$	15	2	30	1	32	64	26	30	9		
	25	2	25	15	55	5		3	13	20	31	1	28	65	25				
								$3\frac{1}{2}$	11	57	32	1	25	66	24	33	8		
2	0	2	25	15	56	0	10	4	10	48	33	1	22	67	23	36	8		
	5	2	26	15	58	25		$4\frac{1}{2}$	9	50	34	1	19	68	22	39	8		
	10	2	26	15	59	20										42	7		
	15	2	26	16	0	15		5	9	2	35	1	16	69	21	45	7		
	20	2	27	16	2	10		$5\frac{1}{2}$	8	21	36	1	13	70	20				
	25	2	27	16	3	5		6	7	45	37	1	11	71	19	48	7		
								$6\frac{1}{2}$	7	14	38	1	8	72	18	51	7		
3	0	2	28	16	5	0	9	7	6	47	39	1	6	73	17	54	6		
	5	2	28	16	6	25										57	6		
	10	2	28	16	7	20		$7\frac{1}{2}$	6	22	40	1	4	74	16	60	5		
	15	2	29	16	9	15		8	6	0	41	1	2	75	15				
	20	2	29	16	10	10		$8\frac{1}{2}$	5	40	42	1	0	76	14	63	5		
	25	2	30	16	11	5		9	5	22	43	58	77	13	66	66	4		
								$9\frac{1}{2}$	5	6	44	56	78	12	69	69	3		
4	0	2	30	16	13	0	8									72	3		
	5	2	31	16	14	25		10	4	52	45	54	79	11	75		2		
	10	2	31	16	15	20		11	4	27	46	52	80	10					
	15	2	31	16	16	15		12	4	5	47	50	81	9	78		2		
	20	2	32	16	17	10		13	3	47	48	47	82	8	81		2		
	25	2	32	16	18	5		14	3	31	49	47	83	7	84		1		
															87		1		
5	0	2	32	16	19	0	7	15	3	17	50	45	84	6	90		0		
	5	2	32	16	20	25		16	3	4	51	44	85	5					
	10	2	33	16	20	20		17	2	53	52	42	86	4					
	15	2	33	16	21	15		18	2	43	53	40	87	3					
	20	2	33	16	21	10		19	2	34	54	39	88	2					
	25	2	33	16	21	5		20	2	26	55	38	89	1					
													9	0					
6	0	2	33	16	21	0	6												

First Eq. of Time.								Second Equation of Time.												
Mean + for App.				App. — for Mean.				Mean + for Apparent.				Apparent — for Mean.								
Arg. Sun's Place.								Argument $\odot$ Mean Anomaly.												
$\odot$	Υ	Δ	δ	μ	Π	I	M	$\odot$	Sign	Sign	Sign	Sign	Sign	Sign	$\odot$					
Pl	0	6	1	7	2	8	A	M	0	1	2	3	4	5	A					
	"	"	"	"	"	"			"	"	"	"	"	"	"					
0	0	0	8	23	8	45	0	0	0	3	47	6	37	7	43	6	45	3	56	30
1		20	8	33	8	35	1	1	8	3	54	6	41	7	43	6	41	3	49	29
2		40	8	43	8	24	2	2	16	4	1	6	45	7	43	6	37	3	42	28
3		59	8	52	8	13	3	3	24	4	8	6	49	7	43	6	33	3	44	27
4	1	19	9	1	8	0	4	4	32	4	15	6	53	7	43	6	29	3	27	26
5	1	39	9	9	7	48	5	5	40	4	21	6	56	7	42	6	24	3	20	25
6	1	58	9	17	7	34	6		47	4	28	7	0	7	42	6	20	3	12	24
7	2	18	9	24	7	20	7		55	4	34	7	3	7	41	6	15	3	5	23
8	2	37	9	30	7	5	8	1	3	4	41	7	6	7	40	6	10	2	57	22
9	2	56	9	35	6	50	9	1	11	4	47	7	9	7	39	6	5	2	49	21
10	3	15	9	40	6	35	10	1	19	4	53	7	12	7	38	6	0	2	42	20
11	3	34	9	44	6	18	11	1	27	4	59	7	15	7	37	5	55	2	34	19
12	3	52	9	47	6	1	12	1	34	5	5	7	18	7	35	5	49	2	26	18
13	4	10	9	50	5	44	13	1	42	5	11	7	20	7	34	5	44	2	18	17
14	4	28	9	52	5	26	14	1	50	5	17	7	23	7	32	5	38	2	10	16
15	4	46	9	53	5	8	15	1	58	5	23	7	25	7	30	5	33	2	2	15
16	5	3	9	54	4	50	16	2	5	5	28	7	27	7	28	5	27	1	54	14
17	5	20	9	54	4	31	17	2	13	5	34	7	29	7	26	5	21	1	46	13
18	5	37	9	53	4	11	18	2	20	5	39	7	31	7	23	5	15	1	38	12
19	5	53	9	51	3	52	19	2	28	5	45	7	33	7	21	5	9	1	30	11
20	6	9	9	49	3	32	20	2	35	5	50	7	35	7	19	5	3	1	22	10
21	6	25	9	46	3	11	21	2	43	5	55	7	36	7	16	4	56	1	14	9
22	6	40	9	42	2	51	22	2	50	6	0	7	37	7	13	4	50	1	6	8
23	6	55	9	37	2	30	23	2	58	6	5	7	39	7	10	4	44		58	7
24	7	9	9	32	2	9	24	3	5	6	10	7	40	7	7	4	37		49	6
25	7	23	9	26	1	48	25	3	12	6	15	7	41	7	4	4	30		41	5
26	7	36	9	19	1	26	26	3	19	6	20	7	41	7	0	4	24		33	4
27	7	48	9	13	1	5	27	3	26	6	24	7	42	6	57	4	17		25	3
28	8	0	9	4		43	28	3	34	6	29	7	43	6	53	4	10		17	2
29	8	12	8	55		22	29	3	41	6	33	7	43	6	49	4	3		8	1
30	8	23	8	45		0	30	3	47	6	37	7	43	6	45	3	56		0	0
Pl	Me. — for Ap.							A	Sign	Sign	Sign	Sign	Sign	Sign	Sign	A				
	Ap. + for Me.							M	11	10	9	8	7	6	M					
$\odot$	Υ	Δ	δ	μ	Π	I	$\odot$	Mean — for Apparent.								Apparent + for Mean.				
	11	5	10	5	9	3														

Table of the Radical Mean Places and Motions of the Moon for Years and Months, Old Stile, Meridian of Greenwich, Latitude $51^{\circ} : 28' \frac{1}{2} \text{ N.}$

1600.	Julian, or Old Stile.											
Months	Mean Place Sun.				Me. Pl. Ap. D				Me. Pl. Ω D R			
	S.	0	'	"	S.	0	'	"	S.	0	'	"
January	1	7	28	7 42	6	8	25	55	10	0	55	28
February	1	9	16	35 48	6	11	53	8	9	29	16	58
March	0	9	25	32 8	6	15	0	18	9	27	48	0
April	0	11	14	0 14	6	18	27	31	9	26	9	31
May	0	0	19	17 45	6	21	48	3	9	24	34	11
June	0	2	7	45 50	6	25	15	17	9	22	55	42
July	0	3	13	3 21	6	28	35	49	9	21	20	22
August	0	5	1	31 27	5	2	3	2	9	19	41	53
September	0	6	19	59 33	7	5	30	15	9	18	3	23
October	0	7	25	17 3	7	8	50	47	9	16	28	4
November	0	9	13	45 9	7	12	18	0	9	14	49	34
December	0	10	19	2 40	7	15	38	32	9	13	14	15
1700.	Julian, or Old Stile.											
January	1	6	5	58 7	9	27	37	10	5	16	44	13
February	1	7	24	26 13	10	1	4	23	5	15	5	43
March	0	8	3	22 33	10	4	11	33	5	13	36	45
April	0	9	21	50 39	10	7	38	46	5	11	58	16
May	0	10	27	8 10	10	10	59	18	5	10	22	56
June	0	0	15	36 15	10	14	26	32	5	8	44	27
July	0	1	20	53 46	10	17	47	4	5	7	9	7
August	0	3	9	21 52	10	21	14	17	5	5	30	38
September	0	4	27	49 58	10	24	41	30	5	3	52	8
October	0	6	3	7 28	10	28	2	2	5	2	16	49
November	0	7	21	35 34	11	1	29	15	5	0	38	19
December	0	8	26	53 5	11	14	49	47	4	29	3	0

Table of the Radical Mean Places and Motions of the Moon
for Years and Months, New Stile, Meridian of Greenwich,
 $51^{\circ}:28\frac{1}{2}'$ N.

1600.	Gregorian, or New Stile.												
Months.	Me. Pl. Moon.				Me Pl. Ap. D				Me. Pl. Ω D R				
	S.	o	'	"	S.	o	'	"	S.	o	'	"	
January	1	3	16	21	52	6	7	19	4	10	1	27	14
February	1	5	4	49	58	6	10	46	17	9	29	48	44
March	o	5	13	46	18	6	13	53	27	9	28	19	46
April	o	7	2	14	24	6	17	20	40	9	26	41	17
May	o	8	7	31	55	6	20	41	12	9	25	5	57
June	o	9	26	o	o	6	24	8	26	9	23	27	28
July	o	11	1	17	31	6	27	28	58	9	21	52	8
August	o	o	19	45	37	7	o	56	11	9	20	13	39
September	o	2	8	13	43	7	4	23	24	9	18	35	9
October	o	3	13	31	13	7	7	43	56	9	16	59	50
November	o	5	1	59	19	7	11	11	9	9	15	21	20
December	o	6	7	16	50	7	14	31	41	9	13	46	1
1700.	Gregorian, or New Stile.												
January	o	1	11	1	42	9	26	23	38	5	17	19	10
February	o	2	29	29	48	9	29	50	51	5	15	40	40
March	o	3	8	26	8	10	2	58	1	5	14	11	42
April	o	4	26	54	14	10	6	25	14	5	12	33	13
May	o	6	2	11	45	10	9	45	46	5	10	57	53
June	o	7	20	39	50	10	13	13	o	5	9	19	24
July	o	8	25	57	21	10	16	33	32	5	7	44	4
August	o	10	14	25	27	10	20	o	45	5	6	5	35
September	o	o	2	53	33	10	23	27	58	5	4	27	5
October	o	1	8	11	31	10	26	48	30	5	2	51	46
November	o	2	26	39	9	11	o	15	43	5	1	13	16
December	o	4	1	56	40	11	3	36	15	4	29	37	57

Table of the Mean Motion of the Moon for Julian Years.

Julian Years.	Mean Mo. D				Mean Mo. Ap. D				Me. Mo. Ω D R			
	S.	°	'	"	S.	°	'	"	S.	°	'	"
100	10	7	50	25	3	19	11	15	4	14	11	15
200	8	15	40	50	7	8	22	30	8	28	22	30
300	6	23	31	15	10	27	33	45	1	12	33	45
400	5	1	21	40	2	16	45	0	5	26	45	0
500	3	9	12	5	6	5	56	15	10	10	56	15
600	1	17	2	30	9	25	7	30	2	25	7	30
700	11	24	52	55	1	14	18	45	7	9	18	45
800	10	2	43	20	5	3	30	0	11	23	30	0
900	8	10	33	45	8	22	41	15	4	7	41	15
1000	6	18	24	10	0	11	52	30	8	21	52	30
2000	1	6	48	20	0	23	45	0	5	13	45	0
3000	7	25	12	30	1	5	37	30	2	5	37	30
4000	2	13	36	40	1	17	30	0	10	27	30	0
Gr. Yrs. fr. 1600.	Years Gregorian from 1600.											
	S.	°	'	"	S.	°	'	"	S.	°	'	"
100	9	24	39	50	3	19	4	34	4	14	8	4
200	7	19	19	40	7	8	9	8	8	28	16	9
300	5	13	59	30	10	27	13	42	1	12	24	13
400	3	21	49	55	2	16	24	57	5	26	35	28
500	1	16	29	45	6	5	29	31	10	10	43	32
600	11	11	9	35	9	24	34	5	2	24	51	37
700	9	5	49	25	1	13	38	39	6	38	59	41
800	7	13	39	50	5	2	49	54	11	23	10	56
900	5	8	19	40	8	21	54	28	4	7	19	0
1000	3	2	59	30	0	10	52	2	8	21	27	5

Table of the Mean Motion of the Moon for 99 Julian Years.

Julian Years.	Mean Mot. D				Me. Mo. D's Ap.				Me. Mo. Ω D R			
	S.	o	'	"	S.	o	'	"	s.	o	'	"
4	5	20	42	49	5	12	46	3	2	17	22	3
8	11	11	25	38	10	25	32	6	5	4	44	6
12	5	2	8	27	4	8	18	9	7	22	6	9
16	10	22	51	16	9	21	4	12	10	9	28	12
20	4	13	34	5	3	3	50	15	0	26	50	15
24	10	4	16	54	8	16	36	18	3	14	12	18
28	3	24	59	43	1	29	22	21	6	1	34	21
32	9	15	42	32	7	12	8	24	8	18	56	24
36	3	6	25	21	0	24	54	27	11	6	18	27
40	8	27	8	10	6	7	40	30	1	23	40	30
44	2	17	50	59	11	20	26	33	4	11	2	33
48	8	8	33	48	5	3	12	36	6	28	24	36
52	1	29	16	37	10	15	58	39	9	15	46	39
56	7	19	59	26	3	28	44	42	0	3	8	42
60	1	10	42	15	9	11	30	45	2	20	30	45
64	7	1	25	4	2	24	16	48	5	7	52	48
68	0	22	7	53	8	7	2	51	7	25	14	51
72	6	12	50	42	1	19	48	54	10	12	36	54
76	0	3	33	31	7	2	34	57	0	29	58	57
80	5	24	16	20	0	15	27	0	3	17	21	0
84	11	14	59	9	5	28	7	3	6	4	43	3
88	5	5	41	58	11	10	53	6	8	22	5	6
92	10	26	24	47	4	23	39	9	11	9	27	9
96	4	17	7	36	10	6	25	12	1	26	49	12
1	4	9	23	3	1	10	39	50	0	19	19	43
2	8	18	46	7	2	21	19	41	1	8	39	26
3	0	28	9	11	4	1	58	32	1	27	59	10

Table of the Mean Motion of the Moon for Days.

Days.	Me. Mo. of the D				Apogee D			Node D R			Days.
	S.	o	'	"	o	'	"	o	'	"	
1	0	13	10	35	0	6	41	0	3	11	31
2	0	26	21	10	0	13	22	0	6	21	30
3	1	9	31	45	0	20	3	0	9	32	29
4	1	22	42	20	0	26	44	0	12	43	28
5	2	5	52	55	0	33	25	0	15	53	27
6	2	19	3	30	0	40	6	0	19	4	26
7	3	2	14	5	0	46	47	0	22	14	25
8	3	15	24	40	0	53	29	0	25	25	24
9	3	28	35	15	1	0	10	0	28	36	23
10	4	11	45	50	1	6	51	0	31	46	22
11	4	24	56	25	1	13	32	0	34	57	21
12	5	8	7	0	1	20	13	0	38	8	20
13	5	21	17	35	1	26	54	0	41	18	19
14	6	4	28	10	1	33	35	0	44	29	18
15	6	17	38	45	1	40	16	0	47	40	17
16	7	0	49	20	1	46	57	0	50	50	16
17	7	13	59	55	1	53	38	0	54	1	15
18	7	27	10	30	2	0	19	0	57	11	14
19	8	10	21	5	2	7	0	1	0	22	13
20	8	23	31	40	2	13	41	1	3	33	12
21	9	6	42	15	2	20	22	1	6	43	11
22	9	19	52	50	2	27	4	1	9	54	10
23	10	3	3	26	2	33	45	1	13	5	9
24	10	16	14	0	2	40	26	1	16	15	8
25	10	29	24	36	2	47	7	1	19	26	7
26	11	12	35	11	2	53	48	1	22	37	6
27	11	25	45	46	3	0	29	1	25	47	5
28	0	8	56	21	3	7	10	1	28	58	4
29	0	22	6	56	3	13	51	1	32	9	3
30	1	5	17	31	3	20	32	1	35	19	2
31	1	18	28	6	3	27	13	1	38	30	1

In Leap Year for one Day sooner in Jan. and Feb. both Stiles.

Table of the Mean Mot. of the Moon for Hours, Min. and Sec.

	Me Mo D			ap D			Ω R				Me Mo D			Ap. D			Ω R			
H	O	'	"	'	"	'	"	H	O	'	"	'	"	'	"		Sec. added to			
M	"	"	"	"	"	"	"	M	"	"	"	"	"	"	"	D hor. semi-				
S	"	"	"	"	"	"	"	S	"	"	"	"	"	"	"	diam. on alt.				
																0	"			
1	0	32	56	0	17	0	8	31	17	1	10	8	38	4	6	0	0			
2	1	5	53	0	33	0	16	32	17	34	7	8	54	4	14	3	1			
3	1	38	49	0	50	0	24	33	18	7	3	9	11	4	22	6	2			
4	2	11	46	1	7	0	32	34	18	39	59	9	28	4	30	9	2			
5	2	44	42	1	24	0	40	35	19	12	55	9	45	4	38	12	3			
6	3	17	39	1	40	0	48	36	19	45	52	10	2	4	46	15	4			
7	3	50	35	1	57	0	56	37	20	18	48	10	19	4	54	18	5			
8	4	23	32	2	14	1	4	38	20	51	45	10	35	5	2	21	6			
9	4	56	28	2	30	1	11	39	21	24	41	10	52	5	10	24	6			
10	5	29	25	2	47	1	19	40	21	57	38	11	8	5	18	27	7			
11	6	2	21	3	4	1	27	41	22	30	34	11	25	5	26	30	8			
12	6	35	18	3	21	1	35	42	23	3	31	11	42	5	34	33	9			
13	7	8	14	3	37	1	43	43	23	36	27	11	59	5	42	36	9			
14	7	41	10	3	54	1	51	44	24	9	24	12	16	5	50	39	10			
15	8	14	7	4	11	1	59	45	24	42	20	12	32	5	57	42	11			
16	8	47	3	4	27	2	7	46	25	15	17	12	48	6	5	45	11			
17	9	20	0	4	44	2	15	47	25	48	13	13	5	6	13	48	12			
18	9	52	56	5	1	2	23	48	26	21	10	13	22	6	21	51	12			
19	10	25	53	5	18	2	31	49	26	54	6	13	39	6	29	54	13			
20	10	58	49	5	34	2	39	50	27	27	3	13	56	6	37	57	13			
21	11	31	46	5	51	2	47	51	27	59	59	14	13	6	45	60	14			
22	12	4	22	6	8	2	55	52	28	32	56	14	30	6	53	63	14			
23	12	37	39	6	24	3	3	53	29	5	52	14	46	7	1	66	15			
24	13	10	35	5	41	3	11	54	29	38	49	15	2	7	9	69	15			
25	13	43	31	6	58	3	19	55	30	11	45	15	19	7	17	72	15			
26	14	16	28	7	15	3	27	56	30	44	42	15	36	7	25	75	16			
27	14	49	24	7	31	3	34	57	31	17	38	15	53	7	33	78	16			
28	15	22	21	7	48	3	42	58	31	50	34	16	10	7	41	81	16			
29	15	55	17	8	5	3	50	59	32	23	31	16	26	7	49	84	16			
30	16	28	14	8	21	3	58	60	32	56	27	16	43	7	57	87	16			
																90	16			

I. Equation of the Moon, or Annual Equation, &c.

Argument of the Sun's Mean Anomaly.

☉	Signs 0.			Signs 1.			Signs 2.			☉									
M	D	Apo.	Node	D	Apo.	Node.	D	Apo.	Node	M									
A	+	—	+	+	—	+	+	—	+	A									
0	0	00	0	00	0	00	5	33	12	46	4	36	9	44	22	16	8	1	30
1	0	12	0	26	0	10	5	43	13	9	4	44	9	50	22	30	8	6	29
2	0	24	0	53	0	19	5	53	13	32	4	52	9	56	22	44	8	11	28
3	0	35	1	19	0	29	6	3	13	55	5	0	10	2	22	58	8	16	27
4	0	47	1	47	0	39	6	13	14	18	5	8	10	7	23	10	8	20	26
5	0	58	2	13	0	48	6	23	14	40	5	16	10	13	23	21	8	24	25
6	1	10	2	40	0	57	6	33	15	1	5	24	10	18	23	33	8	28	24
7	1	21	3	6	1	7	6	43	15	22	5	32	10	23	23	44	8	32	23
8	1	33	3	32	1	17	6	52	15	43	5	40	10	28	23	55	8	36	22
9	1	44	3	59	1	26	7	1	16	4	5	48	10	33	24	5	8	40	21
10	1	55	4	25	1	36	7	10	16	28	5	56	10	38	24	14	8	44	20
11	2	7	4	51	1	45	7	19	16	47	6	5	10	42	24	24	8	47	19
12	2	18	5	17	1	55	7	28	17	7	6	10	10	46	24	33	8	50	18
13	2	30	5	43	2	4	7	37	17	27	6	17	10	50	24	42	8	53	17
14	2	41	6	9	2	14	7	45	17	47	6	24	10	54	24	58	8	56	16
15	2	52	6	35	2	23	7	54	18	7	6	31	10	57	24	57	8	58	15
16	3	3	7	1	2	32	8	3	18	26	6	38	11	0	25	5	9	1	14
17	3	14	7	27	2	41	3	11	18	44	6	45	11	3	25	12	9	3	13
18	3	25	7	52	2	50	3	19	19	3	6	52	11	6	25	18	9	6	12
19	3	36	8	18	2	59	3	27	19	21	6	58	11	8	25	25	9	8	11
20	3	47	8	44	3	8	3	35	19	39	7	4	11	11	25	30	9	10	10
21	3	58	9	9	3	17	8	43	19	57	7	10	11	13	25	35	9	12	9
22	4	9	9	33	3	26	8	50	20	14	7	16	11	15	25	39	9	13	8
23	4	20	9	58	3	35	8	58	20	30	7	22	11	17	25	44	9	15	7
24	4	31	10	22	3	44	9	5	20	46	7	28	11	19	25	48	9	16	6
25	4	42	10	47	3	52	9	12	21	2	7	34	11	21	25	51	9	17	5
26	4	52	11	11	4	1	9	19	21	18	7	39	11	22	25	53	9	18	4
27	5	2	11	35	4	10	9	25	21	33	7	45	11	23	25	55	9	19	3
28	5	13	11	59	4	18	9	32	21	48	7	51	11	24	25	57	9	20	2
29	5	23	12	22	4	27	9	38	22	2	7	56	11	25	25	59	9	21	1
30	5	33	12	46	4	36	9	44	22	16	8	1	11	25	26	0	9	21	0
☉	—	+	—	—	+	—	—	+	—	—	+	—	—	+	—	—	+	—	☉
M	D	Apo.	Node	D	Apo.	Node.	D	Apo.	Node.	D	Apo.	Node	D	Apo.	Node	D	Apo.	Node	M
A	Signs 11.			Sign 10.			Signs 9.												A

I. Equation of the Moon, or Annual Equation, &c.

Argument of the Sun's Mean Anomaly.

☉	Signs 3.			Signs 4.			Signs 5.			☉								
M	D	Apo.	Node	D	Apo.	Node	D	Apo.	Node	M								
A	+	—	+	+	—	+	+	—	+	A								
0	11	25	26	09	21	10	22	45	3	10	5	52	13	14	4	45	30	
1	11	25	26	09	21	9	56	22	32	3	6	5	41	12	50	4	37	29
2	11	25	26	09	21	9	50	22	18	3	1	5	30	12	25	4	28	28
3	11	24	25	59	9	20	9	43	22	3	7	56	5	19	12	14	19	27
4	11	24	25	58	9	20	9	37	21	4	7	51	5	8	11	37	4	26
5	11	23	25	56	9	20	9	30	21	32	7	46	4	57	11	12	4	25
6	11	23	25	54	9	19	9	23	21	17	7	41	4	46	10	46	3	24
7	11	22	25	52	9	18	9	16	21	2	7	35	4	35	10	21	3	23
8	11	21	25	49	9	17	9	9	20	45	7	29	4	24	9	55	3	22
9	11	20	25	45	9	16	9	2	20	28	7	22	4	12	9	23	3	21
10	11	18	25	41	9	15	8	55	20	11	7	16	4	0	9	3	3	20
11	11	16	25	36	9	13	8	47	19	53	7	9	3	49	8	37	3	19
12	11	14	25	31	9	11	8	39	19	35	7	3	3	37	8	11	2	18
13	11	12	25	26	9	9	8	31	19	17	6	57	3	26	7	45	2	17
14	11	10	25	21	9	7	8	23	18	59	6	50	3	14	7	19	2	16
15	11	7	25	15	9	5	8	15	18	39	6	43	3	2	6	52	2	15
16	11	4	25	8	9	3	8	7	18	20	6	36	2	51	6	25	2	14
17	11	1	25	0	9	0	7	58	18	0	6	29	2	39	5	58	2	13
18	10	57	24	52	8	57	7	49	17	40	6	22	2	26	5	31	1	12
19	10	54	24	44	8	54	7	40	17	20	6	15	2	14	5	4	1	11
20	10	50	24	35	8	50	7	31	16	59	6	7	2	2	4	37	1	10
21	10	46	24	26	8	47	7	22	16	38	5	59	1	50	4	10	1	9
22	10	41	24	17	8	44	7	13	16	16	5	51	1	38	3	42	1	8
23	10	37	24	7	8	40	7	4	15	55	5	44	1	26	3	14	1	7
24	10	33	23	56	8	37	6	54	15	33	5	36	1	14	2	46	1	6
25	10	28	23	46	8	33	6	44	15	11	5	28	1	1	2	18	0	5
26	10	23	23	34	8	29	6	33	14	48	5	19	0	49	1	50	0	4
27	10	18	23	23	8	25	6	23	14	24	5	11	0	37	1	23	0	3
28	10	13	23	11	8	20	6	12	14	15	3	0	25	0	56	0	20	2
29	10	8	22	58	8	15	6	2	13	38	4	54	0	13	0	28	0	1
30	10	2	22	45	8	10	5	52	13	14	4	45	0	0	0	0	0	0
☉	—	+	—	—	+	—	—	+	—	—	—	+	—	☉				
M	D	Apo.	Node	D	Apo.	Node	D	Apo.	Node	M								
A	Signs 8.			Signs 7.			Signs 6.			A								

II. Equation of the Moon, or 1. Semi-annual.							III. Equat. of the Moon.				
Argument Sun from the Moon's Apogee.							Arg. $\odot$ α' $\odot$ Ω				
Sign 0.	Sign 1.	Sign 2.	Sign 3.	Sign 4.	Sign 5.		0	1	2		
—	—	—	+	+	+		6	7	8		
0	0	0	0	0	0	0	0	0	0	0	0
00	005	45	170	304	274	3930	0	0	41	41	30
10	135	115	110	184	334	3329	1	2	41	40	29
20	265	175	50	64	384	2728	2	3	42	39	28
30	395	234	580	— 64	434	2127	3	5	43	38	27
40	525	304	510	184	474	1526	4	7	44	37	26
51	45	354	440	304	524	825	5	8	44	36	25
61	165	394	370	414	564	124	6	10	45	35	24
71	285	434	290	525	03	5423	7	11	45	34	23
81	405	474	211	35	43	4622	8	13	46	35	22
91	515	504	131	145	73	3821	9	15	46	31	21
102	35	534	41	255	103	3020	10	16	46	30	20
112	145	553	551	365	123	2119	11	18	47	29	19
122	255	573	461	475	143	1218	12	19	47	28	18
132	355	583	371	595	153	21713	13	21	47	26	17
142	475	593	272	105	162	5210	14	22	47	25	16
152	575	593	172	205	162	4215	15	24	47	24	15
163	75	593	72	305	162	3214	16	25	47	22	14
173	175	582	572	405	152	2213	17	26	47	21	13
183	275	582	462	505	152	1212	18	28	47	19	12
193	365	572	352	595	142	2111	19	29	47	18	11
203	455	562	243	95	131	5110	20	30	46	16	10
213	545	542	133	185	121	409	21	31	46	15	9
224	35	512	23	275	101	308	22	33	46	13	8
234	125	491	513	365	71	197	23	34	45	11	7
244	205	461	403	485	41	86	24	35	45	10	6
254	285	421	293	565	00	575	25	36	44	8	5
264	365	381	184	34	570	464	26	37	43	7	4
274	435	331	64	104	520	353	27	38	43	5	3
284	505	280	544	164	480	242	28	39	42	3	2
294	575	230	424	224	440	121	29	40	41	2	1
305	45	170	304	274	390	0030	30	41	41	0	0
	+	+	+	+	—		5	4	3		
	Sign 11.	Sign 10.	Sign 9.	Sign 8.	Sign 7.	Sign 6.	11	10	9		

IV. Equa. Moon.						V. Equa. Moon.						VI. Equa. Moon.					
Arg. 2 $\odot$ a' $\searrow$ Ω — $\odot$						Mean Evec. + 2 $\searrow$						Me. Evec. + $\odot$ Mean					
a' $\searrow$ Ap.						Anom.						Anom.					
0	+	1	+	2	+	0	+	1	+	2	+	0	+	1	+	2	+
6	—	7	—	8	—	6	—	7	—	8	—	6	—	7	—	8	—
0	//	//		"	"	//	//	"	"	//	"	"	"	"	"	"	0
0	0	30		52	0	42	1	14		0	1	12	2	5	30		
1	1	31		52	1	44	1	14		2	1	15	2	7	29		
2	2	32		53	2	46	1	15		5	1	17	2	8	28		
3	3	32		53	4	47	1	15		7	1	19	2	9	27		
4	4	33		54	6	48	1	16		10	1	21	2	10	26		
5	5	34		54	8	49	1	16		12	1	23	2	11	25		
6	6	35		55	10	50	1	17		15	1	25	2	12	24		
7	7	36		55	12	51	1	17		17	1	27	2	13	23		
8	8	36		56	13	52	1	18		20	1	29	2	14	22		
9	9	37		56	14	53	1	18		22	1	31	2	15	21		
10	10	38		56	15	54	1	19		25	1	33	2	16	20		
11	11	39		57	17	55	1	19		27	1	35	2	17	19		
12	12	39		57	18	56	1	20		30	1	37	2	17	18		
13	13	40		57	19	57	1	20		32	1	39	2	18	17		
14	14	41		58	20	58	1	21		35	1	41	2	19	16		
15	15	42		58	21	59	1	21		37	1	43	2	20	15		
16	16	42		58	22	0	1	22		40	1	44	2	20	14		
17	17	43		58	23	1	1	22		42	1	46	2	21	13		
18	18	44		59	25	1	2	22		44	1	48	2	21	12		
19	19	45		59	26	1	3	23		46	1	49	2	22	11		
20	20	46		59	28	1	4	23		49	1	51	2	22	10		
21	21	47		59	30	1	5	23		51	1	52	2	23	9		
22	22	47		59	31	1	6	24		54	1	54	2	23	8		
23	23	48	1	0	33	1	7	24		56	1	55	2	24	7		
24	24	48	1	0	35	1	8	24		59	1	57	2	24	6		
25	25	49	1	0	36	1	9	24	1	1	1	58	2	24	5		
26	26	49	1	0	37	1	10	25	1	3	2	0	2	24	4		
27	27	50	1	0	38	1	11	25	1	5	2	1	2	25	3		
28	28	51	1	0	40	1	12	25	1	8	2	3	2	25	2		
29	29	51	1	0	41	1	13	25	1	10	2	4	2	25	1		
30	30	52	1	0	42	1	14	25	1	12	2	5	2	25	0		
5	+	4	+	3	+	5	+	4	+	3	+	5	+	4	+	3	+
11	—	10	—	9	—	11	—	10	—	9	—	11	—	10	—	9	—

VII. Equation of the Moon.

Arg. Me. Evcc. — O Me. Anom.

	0 + 6 —	1 + 7 —	2 + 8 —	
	'	' "	' "	
0	0	0 50	1 28	30
1	2	0 52	1 29	29
2	4	0 54	1 30	28
3	6	0 56	1 31	27
4	8	0 57	1 32	26
5	9	0 58	1 33	25
6	11	1 0	1 33	24
7	12	1 1	1 34	23
8	14	1 2	1 35	22
9	16	1 4	1 35	21
10	18	1 5	1 36	20
11	20	1 6	1 36	19
12	21	1 8	1 36	18
13	22	1 9	1 37	17
14	24	1 10	1 37	16
15	26	1 11	1 38	15
16	28	1 13	1 38	14
17	30	1 14	1 39	13
18	31	1 15	1 39	12
19	33	1 17	1 39	11
20	35	1 18	1 40	10
21	37	1 19	1 40	9
22	39	1 20	1 40	8
23	40	1 21	1 40	7
24	42	1 22	1 40	6
25	43	1 23	1 41	5
26	45	1 24	1 41	4
27	46	1 25	1 41	3
28	48	1 26	1 41	2
29	49	1 27	1 41	1
30	50	1 28	1 41	C
	5 + 11 —	4 + 10 —	3 + 9 —	

VIII. Mean Elliptic Equation of the Moon's Centre according to .05505, the mean Eccentricity of the Orbit to Radius 1; or of .55050 Eccentricity to Semi-transverse 100000, or mean Distance a' Earth.

Argument D's corrected Anomaly.

	Signs 0.		Signs 1.		Signs 2.		Signs 3.		Signs 4.		Signs 5.	
	—	—	—	—	—	—	—	—	—	—	—	—
00	0	02	58	30	16	25	6	17	44	5	38	54
10	6	11	3	58	19	53	6	18	8	5	35	49
20	22	22	3	9	23	14	6	18	25	5	32	36
30	18	32	3	14	26	30	6	18	35	5	29	17
40	24	42	3	20	29	42	6	18	38	5	25	50
50	30	52	3	25	32	48	6	18	34	5	22	18
60	37	23	3	30	35	48	6	18	23	5	18	39
70	43	11	3	35	38	43	6	18	5	5	14	53
80	49	19	3	40	41	32	6	17	41	5	11	12
90	55	26	3	45	44	15	6	17	9	5	7	32
101	1	32	3	50	46	53	6	16	30	5	2	57
111	7	38	3	55	49	25	6	15	45	4	58	46
121	13	43	4	0	51	51	6	14	52	4	54	29
131	19	46	4	5	54	11	6	13	52	4	50	5
141	25	48	4	10	56	24	6	12	44	4	45	35
151	31	50	4	14	58	32	6	11	30	4	40	59
161	37	50	4	19	0	34	6	10	9	4	36	18
171	43	48	4	24	2	20	6	8	40	4	31	31
181	49	45	4	28	4	18	6	7	5	4	26	37
191	55	40	4	33	6	26	6	5	23	4	21	39
202	1	33	4	37	7	38	6	3	34	4	16	34
212	7	24	4	41	9	8	6	1	37	4	11	25
222	13	14	4	45	10	32	5	59	34	4	6	90
232	19	14	4	49	11	49	5	57	23	4	0	49
242	24	46	4	53	13	0	5	55	6	3	55	24
252	30	30	4	57	14	4	5	52	41	3	49	52
262	36	11	5	1	15	1	5	50	10	3	44	16
272	41	49	5	5	15	52	5	47	32	3	38	36
282	47	26	5	9	16	36	5	44	46	3	32	50
292	52	58	5	12	17	13	5	41	53	3	27	00
302	58	30	5	16	17	44	5	38	54	3	21	60
	+		+		+		+		+		+	
	Signs 11.	Signs 10.	Signs 9.	Signs 8.	Signs 7.	Signs 6.						

IX. Evac. Equa. of the Moon, or sec. Equa. of the Moon's Cent.

Argument true Evection $\pm \frac{1}{2}$ mean Equation of the Moon's centre according to its Title.

Signs 0.	Signs 1.	Signs 2.	Signs 3.	Signs 4.	Signs 5.
00	00	00	00	00	00
00	0 00	39 42 1	9 7 1	20 25 1	10 9 0
10	1 24 0	40 54 1	9 49 1	20 26 1	9 27 0
20	2 47 0	42 5 1	10 30 1	20 25 1	8 44 0
30	4 10 0	43 16 1	11 10 1	20 22 1	7 59 0
40	5 33 0	44 26 1	11 49 1	20 18 1	7 13 0
50	6 56 0	45 35 1	12 25 1	20 13 1	6 27 0
60	8 19 0	46 43 1	13 1 1	20 6 1	5 39 0
70	9 42 0	47 50 1	13 35 1	19 58 1	4 49 0
80	11 4 0	48 56 1	14 8 1	19 48 1	3 58 9
90	12 26 0	50 1 1	14 40 1	19 37 1	3 5 8
100	13 48 0	51 6 1	15 11 1	19 24 1	2 11 0
110	15 10 0	52 10 1	15 40 1	19 10 1	1 17 0
120	16 30 0	53 13 1	16 8 1	18 54 1	0 31 0
130	17 51 0	54 15 1	16 34 1	18 37 0	59 24 0
140	19 11 0	55 16 1	16 59 1	18 18 0	58 26 0
150	20 31 0	56 16 1	17 22 1	17 59 0	57 27 0
160	21 51 0	57 16 1	17 44 1	17 37 0	56 27 0
170	23 11 0	58 14 1	18 5 1	17 14 0	55 26 0
180	24 30 0	59 11 1	18 24 1	16 50 0	54 24 0
190	25 49 1	0 7 1	18 42 1	16 24 0	53 21 0
200	27 7 1	1 2 1	18 59 1	15 57 0	52 16 0
210	28 25 1	1 56 1	19 14 1	15 28 0	51 11 0
220	29 43 1	2 48 1	19 28 1	14 58 0	50 5 0
230	31 0 1	3 40 1	19 40 1	14 27 0	48 58 0
240	32 16 1	4 31 1	19 51 1	13 54 0	47 50 0
250	33 32 1	5 20 1	20 0 1	13 20 0	46 41 0
260	34 47 1	6 8 1	20 8 1	12 44 0	45 31 0
270	36 2 1	6 55 1	20 14 4	12 7 0	44 21 0
280	37 16 1	7 40 1	20 19 1	11 29 0	43 9 0
290	38 29 1	8 24 1	20 23 1	10 50 0	41 56 0
300	39 42 1	9 7 1	20 25 1	10 9 0	40 43 0
+	+	+	+	+	+
Signs 11.	Signs 10.	Signs 9.	Signs 8.	Signs 7.	Signs 6.

X. Compound Variation Equation of the Moon.											
Argument of the Moon equated from the ☉'s true Place.											
D a' ☉	Signs +	0 +	Signs +	1. +	Signs +	2. +	Signs -	3. -	Signs -	4. -	Signs -
	'	"	'	"	'	"	'	"	'	"	"
0	0	0	32	19	31	12	2	0	34	26	34
1	1	19	32	56	30	29	3	19	35	4	33
2	2	38	33	30	29	43	4	38	35	40	32
3	3	57	34	1	28	55	5	57	36	13	31
4	5	15	34	29	28	6	7	15	36	43	30
5	6	33	34	55	27	15	8	32	37	11	30
6	7	50	35	19	26	22	9	48	37	37	29
7	9	6	35	40	25	27	11	4	37	59	28
8	10	22	35	58	24	30	12	19	38	19	27
9	11	38	36	14	23	31	13	34	38	36	26
10	12	33	36	27	22	30	14	48	38	51	25
11	14	7	36	37	21	27	16	12	39	3	24
12	15	20	36	44	20	23	17	15	39	12	23
13	16	31	36	49	19	17	18	27	39	18	22
14	17	40	36	50	18	10	19	37	39	22	20
15	18	48	36	49	17	1	20	46	39	21	19
16	19	55	36	45	15	50	21	53	39	20	18
17	21	0	36	38	14	38	22	58	39	15	17
18	22	4	36	29	13	26	24	1	39	8	16
19	23	7	36	17	12	13	25	3	38	58	14
20	24	8	36	3	10	59	26	4	38	45	13
21	25	7	35	46	9	43	27	4	38	29	12
22	26	4	35	26	8	27	28	2	38	10	10
23	26	59	35	3	7	10	28	58	37	49	9
24	27	51	34	38	5	52	29	52	37	25	8
25	28	41	34	10	4	34	30	43	36	58	6
26	29	29	33	39	3	16	31	32	36	28	5
27	30	15	33	6	1	57	32	19	35	55	4
28	30	58	32	30	0	38	33	4	35	20	2
29	31	39	31	52	0	41	33	46	34	43	1
30	32	19	31	12	2	0	34	26	34	3	0
D a' ☉	-	-	-	-	+	+	+	+	+	+	D a' ☉
	Signs 11.	Signs 10.	Signs 9.	Signs 8.	Signs 7.	Signs 6.					

Equa. of me. Vari. D in Oct. or me. Diff. O to Vari. in Perig. & Apo. O a' Earth				Correction of Mean Variation.											
Argum. D a' O.				Argument O Mean Anomaly.											
0	1	2		0	1	2	3	4	5						
—	—	—		Dec.	Dec.	Dec.	Dec.	Dec.	Dec.						
6	7	8		×rs.	×rs.	×rs.	×rs.	×rs.	×rs.						
+	+	+													
"	"	"	"												
0	0	107	107	30	0	.92	.80	.48	.02	.49	.86	30			
1	4	109	105	29	1	.92	.80	.47	.00	.51	.87	29			
2	8	111	103	28	2	.92	.79	.45	.02	.52	.88	28			
3	13	112	101	27	3	.92	.78	.43	.04	.54	.89	27			
4	18	114	98	26	4	.92	.77	.41	.05	.55	.89	26			
5	22	116	95	25	5	.92	.76	.40	.07	.56	.90	25			
6	26	117	92	24	6	.91	.75	.38	.09	.58	.91	24			
7	30	119	89	23	7	.91	.74	.36	.10	.59	.91	23			
8	34	120	86	22	8	.91	.73	.35	.12	.60	.92	22			
9	38	121	83	21	9	.91	.72	.34	.14	.62	.92	21			
10	42	122	80	20	10	.90	.71	.33	.16	.63	.93	20			
11	46	123	77	19	11	.90	.70	.31	.18	.65	.94	19			
12	50	123	74	18	12	.90	.69	.30	.20	.66	.95	18			
13	54	124	70	17	13	.90	.68	.28	.21	.68	.95	17			
14	58	124	66	16	14	.89	.67	.26	.22	.69	.96	16			
15	62	124	62	15	15	.89	.66	.25	.24	.70	.96	15			
16	66	124	58	14	16	.89	.65	.24	.25	.71	.97	14			
17	70	124	54	13	17	.88	.64	.22	.27	.72	.97	13			
18	74	123	50	12	18	.88	.63	.20	.28	.73	.97	12			
19	77	123	46	11	19	.88	.62	.18	.30	.75	.98	11			
20	80	122	42	10	20	.87	.61	.17	.32	.76	.98	10			
21	83	121	38	9	21	.87	.60	.16	.34	.77	.99	9			
22	86	120	34	8	22	.86	.59	.14	.36	.78	.99	8			
23	89	119	30	7	23	.86	.58	.12	.37	.79	.99	7			
24	92	117	26	6	24	.85	.57	.10	.39	.80	.99	6			
25	95	116	22	5	25	.85	.55	.09	.41	.81	1.00	5			
26	98	114	18	4	26	.84	.54	.07	.42	.82	1.00	4			
27	101	112	14	3	27	.83	.52	.05	.43	.83	1.00	3			
28	103	111	9	2	28	.82	.51	.04	.45	.84	1.00	2			
29	105	109	4	1	29	.81	.50	.03	.47	.85	1.00	1			
30	107	107	0	0	30	.80	.48	.02	.49	.86	1.00	0			
	—	—	—			×rs.	×rs.	×rs.	×rs.	×rs.	×rs.				
	11	10	9			11	10	9	8	7	6				
	+	+	+												
	5	4	3												

Mean Reduction Equa. of the Moon to the Ecliptic.						Moon's Latitude at the mean Inclination of her Orbit.						
Arg. D in orb a' Ω 1 Equa.						Arg. D in her Orbit a' Ω 1 equated.						
0.	6.	1.	7.	2.	8.	0.	N. A.	1.	N. A.	2.	N. A.	
—	—	—	—	—	—	6.	S. A.	7.	S. A.	8.	S. A.	
'	"	'	"	'	"	'	"	'	"	'	"	
00	06		26		230	00	0	02	34	44	27	230
10	146		95		5529	10	5	222	38	424	29	4229
20	296		155		4728	20	10	452	43	184	32	1628
30	436		215		3927	30	16	72	47	504	34	4627
40	586		275		3026	40	21	292	52	204	37	1026
51	126		325		2025	50	26	512	56	454	39	2925
61	266		375		1024	60	32	123	1	94	41	4324
71	416		415		023	70	37	323	5	284	43	5223
81	556		454		5022	80	42	523	9	454	45	5622
92	96		484		3921	90	48	113	13	584	47	5521
102	236		514		2820	100	53	293	18	74	49	4920
112	376		544		1719	110	58	463	22	124	51	3619
122	506		564		518	121	4	33	26	144	53	1918
133	36		573		5317	131	9	183	30	134	54	5717
143	166		573		4116	141	14	323	34	74	56	2916
153	296		573		2915	151	19	443	37	584	57	5615
163	416		573		1614	161	24	553	41	444	59	1614
173	536		573		313	171	30	43	45	275	0	3213
184	56		562		5012	181	35	123	49	55	1	4212
194	176		542		3711	191	40	183	52	405	2	4611
204	286		512		2310	201	45	223	56	105	3	4510
214	396		482		99	211	50	253	59	355	4	399
224	506		451		558	221	55	251	2	575	5	278
235	06		411		417	232	0	234	6	135	6	97
245	106		371		266	242	5	194	9	265	6	456
255	206		321		125	252	10	134	12	335	7	165
265	306		270		584	262	15	44	15	375	7	424
275	396		210		433	272	19	534	18	355	8	23
285	476		150		292	282	24	394	21	295	8	162
295	556		90		141	292	29	234	24	185	8	241
306	26		20		00	302	34	44	27	25	8	280
+	+	+				11.	S. D.	10.	S. D.	9.	S. D.	
11.	5.	10.	4.	9.	3.	5.	N. D.	4.	N. D.	3.	N. D.	

I. Equation of the Moon's mean to her true Latitude for the present Inclination of her Orbit.								II. Equa. of the D's mean to her true Lat. for the present from me. Incl. of her Orb.							
Arg. 2 Δ a' $\odot$ — the foregoing Arg.								Arg. I. Equa. — $\odot$ me. Ano							
0.	N. A.	1.	N. A.	2.	N. A.			0.	S.	1.	S.	2.	S.		
5.	S. A.	7.	S. A.	8.	S. A.			6.	N.	7.	N.	8.	N.		
	'	"	'	"	'	"			"	"	"				
0	0	0	4	25	7	40	30	0	0	14	24	30			
1	0	9	4	33	7	45	29	1	0	14	24	29			
2	0	18	4	41	7	49	28	2	1	14	24	28			
3	0	28	4	49	7	54	27	3	1	15	24	27			
4	0	37	4	57	7	58	26	4	2	15	25	26			
5	0	46	5	4	8	2	25	5	2	15	25	25			
6	0	55	5	12	8	6	24	6	3	16	25	24			
7	1	4	5	19	8	9	23	7	3	16	24	23			
8	1	14	5	27	8	13	22	8	4	16	26	22			
9	1	23	5	34	8	16	21	9	4	17	26	21			
10	1	32	5	41	8	20	20	10	5	17	26	20			
11	1	41	5	48	8	23	19	11	5	18	26	19			
12	1	50	5	55	8	26	18	12	6	18	26	18			
13	1	59	6	2	8	29	17	13	6	18	26	17			
14	2	8	6	9	8	31	16	14	7	19	27	16			
15	2	17	6	16	8	34	15	15	7	19	27	15			
16	2	26	6	22	8	36	14	16	8	19	27	14			
17	2	35	6	29	8	39	13	17	8	20	27	13			
18	2	44	6	34	8	41	12	18	9	20	27	12			
19	2	53	6	41	8	42	11	19	9	20	27	11			
20	3	1	6	47	8	44	10	20	10	21	27	10			
21	3	10	6	53	8	46	9	21	10	21	27	9			
22	3	19	6	59	8	47	8	22	11	21	28	8			
23	3	27	7	4	8	48	7	23	11	22	28	7			
24	3	35	7	10	8	49	6	24	12	22	28	6			
25	3	44	7	15	8	50	5	25	12	22	28	5			
26	3	52	7	21	8	51	4	26	13	22	28	4			
27	4	1	7	26	8	52	3	27	13	23	28	3			
28	4	9	7	31	8	52	2	28	13	23	28	2			
29	4	17	7	36	8	52	1	29	13	23	28	1			
30	4	25	7	40	8	52	0	30	14	24	28	0			
11. S. D.								11. N.							
5. N. D.								5. S.							
10. S. D.								10. N.							
4. N. D.								4. S.							
9. S. D.								9. N.							
3. N. D.								3. S.							

Mean horizontal Parallax of the Moon in Syzies Eccentricity 55050 to the Middle State of her Orbit her me. dist. fr. Earth 100000												I. Equation of the Moon's hor. Paral.			II. Equation of the Moon's horizontal Parallax.		
Argument D Anomaly 7 times equated.												Arg. me. Evac.			Arg. D a' O.		
Sig. 0.	Sig. 1.	Sig. 2.	Sig. 3.	Sig. 4.	Sig. 5.	0 —	1 —	2 —	0 —	1 —	2 —	0 —	1 —	2 —	0 —	1 —	2 —
+	+	+	+	+	+	6 +	7 +	8 +	6 —	7 —	8 —	6 +	7 +	8 +	6 —	7 —	8 —
0 54	37 54	57 55	56 57	24 59	5 60	26	42	36	21	0	15	45	30	19	0	15	45
1 54	37 34	59 55	59 57	27 59	9 60	28	42	35	20	0	16	46	29	20	0	16	46
2 54	37 55	0 56	1 57	31 59	12 60	30	42	35	19	0	17	46	28	21	0	17	46
3 54	37 55	2 56	4 57	34 59	15 60	32	42	35	18	0	18	47	27	22	0	18	47
4 54	38 55	3 56	6 57	38 59	18 60	33	42	34	18	1	19	47	26	23	1	19	47
5 54	38 55	5 56	9 57	42 59	21 60	34	42	34	17	1	20	48	25	24	1	20	48
6 54	38 55	6 56	12 57	45 59	24 60	36	41	34	17	1	21	49	24	25	1	21	49
7 54	38 55	8 56	14 57	49 59	27 60	37	41	33	16	1	22	50	23	26	1	22	50
8 54	38 55	9 56	17 57	52 59	30 60	38	41	33	15	2	23	51	22	27	2	23	51
9 54	39 55	11 56	20 57	56 59	33 60	39	41	33	15	2	24	52	21	28	2	24	52
10 54	39 55	12 56	22 57	59 59	36 60	41	41	32	14	2	25	52	20	29	2	25	52
11 54	39 55	15 56	25 58	2 59	39 60	42	41	32	14	2	26	53	19	30	2	26	53
12 54	40 55	16 56	28 58	6 59	42 60	43	40	31	13	3	27	54	18	31	3	27	54
13 54	40 55	18 56	31 58	9 59	45 60	44	40	31	12	3	28	54	17	32	3	28	54
14 54	42 55	20 56	34 58	13 59	47 60	45	40	31	11	4	29	55	16	33	4	29	55
15 54	42 55	22 56	38 58	16 59	50 60	46	40	30	10	4	30	55	15	34	4	30	55
16 54	42 55	24 56	41 58	19 59	53 60	47	40	30	9	5	31	56	14	35	5	31	56
17 54	43 55	26 56	44 58	21 59	56 60	48	40	29	9	5	33	56	13	36	5	33	56
18 54	44 55	28 56	47 58	25 59	59 60	49	40	29	8	6	34	57	12	37	6	34	57
19 54	45 55	30 56	50 58	28 60	1 60	50	39	28	7	6	36	57	11	38	6	36	57
20 54	46 55	32 56	53 58	32 60	4 60	50	39	27	6	7	37	57	10	39	7	37	57
21 45	47 55	34 56	56 58	35 60	6 60	51	39	26	5	7	38	58	9	40	7	38	58
22 45	48 55	36 56	59 58	39 60	9 60	51	39	25	5	8	39	58	8	41	8	39	58
23 45	49 55	39 57	2 58	42 60	11 60	52	38	25	4	9	40	58	7	42	9	40	58
24 45	50 55	41 57	5 58	46 60	14 60	52	38	24	4	10	41	59	6	43	10	41	59
25 45	51 55	44 57	8 58	49 60	16 60	53	37	24	3	10	41	59	5	44	10	41	59
26 45	52 55	46 57	11 58	52 60	18 60	53	37	23	3	11	42	59	4	45	11	42	59
27 45	53 55	49 57	15 58	56 60	20 60	54	37	23	2	12	43	60	3	46	12	43	60
28 45	55 55	51 57	18 58	59 60	22 60	54	36	22	1	13	43	60	2	47	13	43	60
29 45	56 55	54 57	21 59	2 60	24 60	54	36	22	1	14	44	60	1	48	14	44	60
30 45	57 55	56 57	24 59	5 60	26 60	54	36	21	0	15	45	60	0	49	15	45	60
+	+	+	+	+	+	11 —	10 —	9 —	11 —	10 —	9 —	+	+	+	+	+	+
Sig. 11.	Sig. 10.	Sig. 9.	Sig. 8.	Sig. 7.	Sig. 6.	5 +	4 +	3 +	5 —	4 —	3 —						

A Catalogue of Historical Eclipses of the Sun and Moon from Ricciolus.

Before Christ.

754, July 5. But April 21 by an old calendar; an eclipse of the Sun. Rome began to be built.

721, March 19. A total eclipse of the Moon;—Assyrian empire ended;—Babylonian established.

585, May 28. Eclipse of the Sun predicted by Thales;—Peace ensued betwixt the Medes and the Lydians.

523, July 16. An eclipse of the Moon, followed by the death of Cambyfes.

502, Nov. 19. An eclipse of the Moon, followed by the slaughter of the Sabines, and the death of Valerius Publicola.

491, April 25. An eclipse of the Moon, followed by a great famine at Rome, and the beginning of the Peloponnesian war.

463, April 30. An eclipse of the Sun;—War with the Persians falling off from the Egyptians.

431, Aug. 3. A total eclipse of the Sun;—A comet and plague at Athens.

413, Aug. 27. A total eclipse of the Moon;—Nicias and his ship destroyed at Syracuse.

394, Aug. 14. An eclipse of the Sun;—The Persians beat Conon in a sea engagement.

168, June 21. A total eclipse of the Moon;—Next day Perseus, King of Macedonia, conquered by Paulus Emilius.

Since Christ.

59, April 30. An eclipse of the Sun;—A prodigy for the death of Agrippinus by Nero.

237, April 12. A total eclipse of the Sun;—Reign of the Gordiani;—Short persecution of the Christians.

306, July 27. An eclipse of the Sun;—Stars appeared, and the Emperor Constantius died.

A great

Since Christ,
840, May 4.

A great eclipse of the Sun;—Lewis the Pious died six months after.

1009.

An eclipse of the Sun;—Jerusalem taken by the Saracens.

1133, Aug. 2.

A great eclipse of the Sun, Stars are seen;—A schism in the church by two Popes at once.

1493.

An eclipse of the Sun; Christopher Columbus drove on the island of Jamaica, where he was refused provisions; but he affrighted the inhabitants by his prediction of this eclipse, threatening them with a plague, of which that was to be the token, and so got supplied.

A P P E N D I X.

AS a considerable space of time has elapsed since my first proposing to publish the foregoing treatise, and all the eclipses calculated therein are past, though the precepts and mode of calculation will ever remain the same, yet I flatter myself that the calculation of two or three eclipses, which are still to happen, may be acceptable to my readers. I shall here present them with a correct computation of two very remarkable lunar eclipses, which will be visible in England in the course of this present year, 1783; and also with the calculation of a solar eclipse, which will happen in the year 1793, and will be the greatest that will be seen in England during the remaining part of this century. And shall first begin with a total eclipse of the Moon, which will happen on Wednesday, the 18th of March, 1783, as follows:

	H.	M.	S.	
Ecliptic 8 mean time in the meridian of Greenwich	9	27	53	
	0	'	"	
Sun's longitude then	♈	28	11 26	
Moon in the ecliptic	♊	28	11 26	
Moon's latitude, S. A.		2	56	
	D.	H.	M.	S.
Ecliptic 8 mean time at Green. 1783, March	18	9	27	53
Equation of apparent time, —			8	11
Ecliptic 8 apparent time at Greenwich	18	9	19	42
Double reduction in time —				23
Apparent time of the middle of eclipse, Green.	18	9	19	19
Difference of merid. between Green. and Nor. +			5	00
Apparent time of the middle at Norwich	18	9	24	19
Horizontal parallax D			57	59
Ditto of the Sun				9
Sum			58	8
Sun's semi-diameter, —			16	10
Semi-diameter of the earth's shadow			41	58
Add				50
Semi-diam. of the earth's shadow and atmosphere			42	48
Semi-diameter of the Moon, +			15	57
Sum			58	45
Nearest approach cent. of Moon and earth's shad. —			2	55
Parts deficient			55	50
				Digits

Digits eclipsed	6	'	"
	21	2	4

Motion of semi-duration			35 20
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Time of ditto	H.	M.	S.
	1	51	44

Motion of semi-duration in total darkness			13 59
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Time of ditto			43 8
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	H.	M.	S.		H.	M.	S.
Ap. time middle	9	24	19	App. time middle	9	24	19
Semi-dur.—and +	1	51	44	Semi-dur. in dark.		43	8
Begin	7	32	35	Begin	8	41	11
End	11	16	3	End	10	7	27

Whence the apparent Time at Norwich, March 18th, 1783.

	H.	M.	S.
Beginning of the eclipse	7	32	35
Beginning of total darkness	8	41	11
Middle of the eclipse	9	24	19
Ecliptic 8 at Norwich	9	24	42
End of total darkness	10	7	27
End of the eclipse	11	16	3

Digits eclipsed	21	2	4
Duration of total darkness	1	26	16
Duration of the eclipse	3	43	28

A Calculation of a Lunar Eclipse, which will happen on Wednesday, the 10th of September, 1783, for the Meridian of Norwich.

	H.	M.	S.
Ecliptic 8 mean time at Greenwich	11	38	20
	0	'	"
Sun's longitude then	18	3	13
Moon in the ecliptic	18	3	13
Moon's latitude, S. D.		2	24
Ecliptic 8 mean time at Greenwich	11	38	20
Equation of apparent time, +		3	23
Ecliptic 8 apparent time at Greenwich	11	41	43
Double reduction in time, +			20
Apparent time of the middle eclipse at Greenwich	11	42	3
Diff. of merid. between Greenwich and Norwich, +		5	0
Apparent			

		0	'	"
App. time of the middle of the eclipse at Norwich	11	47	3	
Horizontal parallax of the Moon	-	59	13	
Ditto of the Sun	-	-	9	
Sum	-	59	22	
Sun's semi-diameter, —	-	15	59	
Semi-diameter of the earth's shadow	-	43	23	
Add	-	-	50	
Semi-diameter of the earth's shadow and atmosphere	44	13		
Semi-diameter of the Moon add	-	16	9	
Sum	-	60	22	
Nearest approach of centre's D and earth's shadow, —	2	36		
				' "
Parts deficient	-	57	46	
Digits eclipsed	-	21 ⁰	27	41

Motion of semi-duration - - - 3618

		H.	M.	S.
Time of ditto	-	1	53	50
Motion of semi-duration in total darkness	-			1677
Time of ditto	-	27	57	

		H.	M.	S.		H.	M.	S.
Ap. time mid. at Nor.	11	47	3		Ditto	11	47	3
Semi-dura. — and +	1	53	50		Semi-du. dark.—& +	27	57	
Begin	-	9	53	13	Darkness begins	11	19	6
End	-	13	40	53	Ditto end	12	15	0

Whence the Apparent Times at Norwich as under:

		H.	M.	S.
Eclipse begins	-	9	53	13
Beginning of total darkness	-	11	19	6
Ecliptic 8	-	11	46	43
Middle of the eclipse	-	11	47	3
Total darkness end	-	12	15	0
End of the eclipse	-	13	40	53
		0	'	"
Digits eclipsed	-	21	27	41
Duration of total darkness	-	0	55	54
Duration of eclipse	-	3	47	40

A Calculation of a Solar Eclipse that will happen on Thursday September the 5th, 1793, for the Meridian of the City of Norwich.

	D.	H.	M.	S.
Ecliptic $\odot$ mean time at Greenwich, Sept.	4	23	53	41
Diff. of Merid. between Greenwich and Nor. +			5	
Ecliptic $\odot$ mean time at Norwich	4	23	58	41
Equation of apparent time +			1	43
Ecliptic $\odot$ app. time in the merid. of Norwich	5	0	0	24
		0	'	"
Longitude of the $\odot$ and D in the ecliptic M	13	16	36	
Moon's true latitude, N. A			40	39
Moon's semi-diameter			14	50
Sun's ditto			15	58
Moon's horizontal parallax			54	26
Sun's ditto				9
Moon's horary motion			29	39
Sun's ditto			2	26
Horary motion of the D a' $\odot$			27	13
Sun's declination, N.		6	34	55
Sun's right ascension	164	35	27	
Apparent time from noon		+	6	00
Right ascension of medium celi	164	41	27	
Complement short of M		15	18	33
Medium celi in the ecliptic	M 13	23	2	
Meridian angle		67	24	19
Declination of the culminating point, N. +		6	32	31
Altitude of the equator at Norwich		37	15	0
Altitude of medium celi		43	47	31
Altitude of the nonagesima degree		48	13	24
Distance of medium celi from nonagesima		21	9	3
Nonagesima degree in	Ω 22	13	59	
Moon from the nonagesima		21	2	37
			'	"
Horizontal parallax D a' $\odot$			54	17
Parallax in longitude D a' $\odot$			14	28
		0	'	"
Moon's visible longitude	M 13	31	4	
Moon's latitude, N. A.			40	39
Parallax in latitude D a' $\odot$			36	10
Moon's visible latitude, N. A.			4	29

To the nonagesima add three signs, the ascendent is in M 22:13:59, whence the luminaries are between the nonagesima and ascendent, or in the oriental quadrant; so the visible $\odot$ happen before the true.

At

	D.	H.	M.	S.
At one hour before eclips. δ me. time at Green.	4	22	53	41
Difference of meridians +	-	-	5	
Mean time at Norwich	4	22	58	41
Equation of apparent time +	-	-	1	43
Apparent time at Norwich, Sept.	4	23	0	24
Sun's place then	☾	13	14	11
Moon in the ecliptic	☾	12	44	43
Horizontal parallax $\textcircled{D} a' \odot$	-	-	53	53
Parallax in longitude $\textcircled{D} a' \odot$	-	-	22	24
Visible ecliptic place of the $\textcircled{D}$	☾	13	7	7
Ditto at the ecliptic δ	☾	13	31	4
Visible hourly motion $\textcircled{D}$	-	-	23	57
Hourly motion of the $\odot$	-	-	2	25
Visible hourly motion $\textcircled{D} a' \odot$	-	-	21	32
Moon's true latitude, N. A.	-	-	37	53
Parallax in latitude $\textcircled{D} a' \odot$	-	-	32	47
Moon's visible latitude, N. A.	-	-	5	6

As visible hourly motion $\textcircled{D} a' \odot 21': 32''$ to 1 hour, so is parallax in longitude $\textcircled{D} a' \odot$ to interval, from true to visible, $\delta 40': 5''$.

	D.	H.	M.	S.
Apparent time of ecliptic δ Norwich	5	0	0	24
Interval in time subtr.	-	-	40	5
Visible δ apparent time at Norwich	4	23	20	19
Sun's longitude then	☾	13	14	59
Moon's longitude then	☾	12	55	18
Moon's latitude then, N. A.	-	-	38	48
Parallax in longitude $\textcircled{D} a' \odot$	-	-	22	37
Moon's visible longitude	☾	13	17	55
Parallax in latitude $\textcircled{D} a' \odot$	-	-	27	51
Moon's visible latitude, N. A.	-	-	10	57
At one hour before visible δ	4	22	20	19
Sun's longitude then	☾	13	12	34
Longitude of the Moon	☾	12	23	25
Moon's latitude, N. A.	-	-	36	2
Horizontal parallax $\textcircled{D} a' \odot$	-	-	53	58
Moon's visible longitude	☾	12	53	5
Ditto at visible δ	☾	13	17	55
Visible hourly motion $\textcircled{D}$	-	-	24	50
Hourly motion of the $\odot$	-	-	2	25
Visible hourly motion $\textcircled{D} a' \odot$	-	-	22	25
Parallax in latitude $\textcircled{D} a' \odot$	-	-	30	9
Moon's visible latitude, N. A.	-	-	5	53
At one hour after visible δ	5	0	20	19
Sun's longitude	☾	13	17	24
Moon's ditto	☾	13	27	11
Moon's latitude, N. A.	-	-	41	34
Horizontal parallax of the $\textcircled{D}$	-	-	54	46
			Parallax	

	D.	H.	M.	S.
Parallax in longitude $\mathcal{D}$ a' $\odot$	-	-	15	12
Moon's visible longitude	-	-	13	42
Ditto at visible δ	-	-	13	17
Visible hourly motion $\mathcal{D}$	-	-	24	28
Hourly motion $\odot$	-	-	2	25
Visible hourly motion $\mathcal{D}$ a' $\odot$	-	-	22	3
Parallax in latitude $\mathcal{D}$ a' $\odot$	-	-	36	31
Moon's visible latitude, N. A	-	-	5	3
			0	' "
Angle of visible way of the $\mathcal{D}$ at visible δ	-	1	4	26
Motion from visible δ to greatest obscuration	-			7
			H.	M.
Visible δ , Sept. 5, 1793, A. M.	-	11	20	19
Time from visible δ to greatest obscuration	-			19
Time of greatest obscuration	-	11	20	00
			'	"
Visible distance of centres of the $\odot$ and $\mathcal{D}$ at greatest obscuration	-	-	10	56
Visible motion of semi-duration	-	-	28	48
			0	' "
Angle of visible way $\mathcal{D}$ with the ecliptic from beginning of eclipse to greatest obscuration	-	12	43	31
Visible motion in longitude from beginning of eclipse to greatest obscuration	-		27	45
			H.	M.
Time of incidence	-	1	14	16
Time of repletion	-	1	15	30
Semi-diameter of the penumbra	-		30	48
Parts deficient	-		19	52
			0	' "
Digits eclipsed	-	7	27	56
Whence the apparent time of this eclipse at Norwich, Sept. 5, 1793, A. M.				
			H.	M.
The eclipse begin at Norwich apparent time, A. M.	-	10	5	44
Greatest obscuration	-	11	20	00
Visible δ	-	11	20	19
End of the eclipse, P. M.	-	12	35	30
			4	00
			58	' "
Digits eclipsed	-	7	27	56
Duration of the eclipse	-	2	29	46

F I N I S.

